Enhancing rural connectivity

June 2021

Important Notice

This final report (the "Final Report") has been prepared by Deloitte LLP ("Deloitte") for Vodafone Group Plc in accordance with the contract with them dated 29/03/2021 ("the Contract") and on the basis of the scope and limitations set out below.

The Final Report has been prepared solely for the purposes of describing the economic and social impacts of improved rural connectivity, as set out in the Contract. It should not be used for any other purpose or in any other context, and Deloitte accepts no responsibility for its use in either regard.

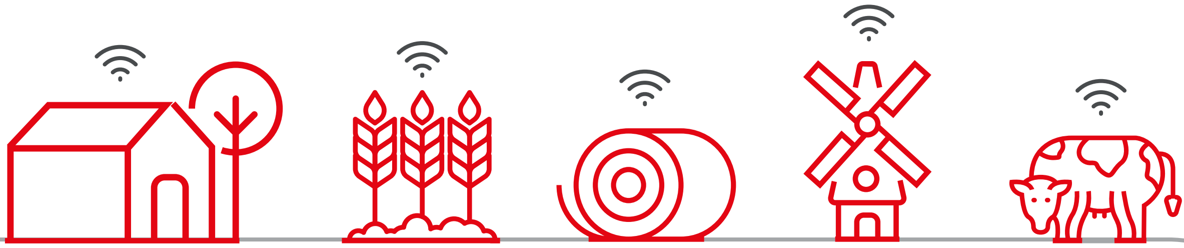
The Final Report is provided exclusively for Vodafone Group Plc's use under the terms of the Contract. No party other than Vodafone Group Plc is entitled to rely on the Final Report for any purpose whatsoever and Deloitte accepts no responsibility or liability or duty of care to any party other than Vodafone Group Plc in respect of the Final Report or any of its contents.

The information contained in the Final Report has been obtained from Vodafone Group Plc and third party sources that are clearly referenced in the appropriate sections of the Final Report. Deloitte has neither sought to corroborate this information nor to review its overall reasonableness. Further, any results from the analysis contained in Final Report are reliant on the information available at the time of writing the Final Report and should not be relied upon in subsequent periods.

Any decision to invest, conduct business, enter or exit the markets considered in the Final Report should be made solely on independent advice and no information in the Final Report should be relied upon in any way by any third party. This Final Report and its contents do not constitute financial or other professional advice, and specific advice should be sought about your specific circumstances. In particular, the Final Report does not constitute a recommendation or endorsement by Deloitte to invest or participate in, exit, or otherwise use any of the markets or companies referred to in it. To the fullest extent possible, both Deloitte and Vodafone Group Plc disclaim any liability arising out of the use (or non-use) of the Final Report and its contents, including any action or decision taken as a result of such use (or non-use).

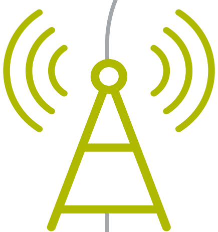
Overview

This report provides a blueprint of how governments and policymakers can assess the benefits of enhanced connectivity in rural areas and examples of how this could be achieved.



The reports covers the benefits of connectivity as an enabler of rural communities, the challenges in developing rural connectivity and policy tools used by governments to support rural connectivity.

The key takeaways are:



The EU has demonstrated the commitment and political willingness to closing the gap in rural connectivity with the Digital Decade targets to deliver **enhanced fixed and mobile connectivity to all citizens**

The Recovery and Resilience Facility provides the **momentum to achieve these goals,** with significant investment committed to digital transformation.

However, the funding available **will not be sufficient to overcome the current low levels of connectivity in rural communities** and the challenges to developing enhanced connectivity in these areas

Enhancing connectivity in these areas brings a wide-range of benefits supporting the European Commission's long-term vision for **vibrant, connected and sustainable rural areas:**

Improved quality of life through access to services such as **e-health, digital learning** and a broad range of **e-government services**

Enhanced economic outcomes by enabling firms to create new products and services and promote rural diversification

Increased social inclusion and wellbeing of those in rural communities by increasing social and economic participation in rural areas

Reduced carbon emissions and **slower environmental degradation** by improving efficiency and promoting the circular economy

Achieving efficient use of funds will require **governments to take a local or regional view** of the benefits and costs, as these will vary depending on the characteristics of rural areas.

For this governments will require a set of frameworks to **understand and assess the benefits of enhanced connectivity**

Appropriate policies can complement this to encourage collaboration between public and industry stakeholders, ensuring that public funds are used efficiently to deliver the greatest benefits

Executive Summary

The European Commission (EC) is committed to strengthening the presence of rural areas in Europe. To that end, the EC is forming its long-term vision for rural communities, which have lagged in terms of social and economic development in recent decades.[1,2] The role of digitalisation and connectivity can act as a catalyst for socio-economic progress across four key pillars, which have been identified by the public consultation on the EU's long-term vision for rural.[3]

The political commitment to enhance digitalisation across Europe is reflected in the decision to allocate at least 20% of the Recovery and Resilience Facility (RRF) to digital investments. The funds are expected to contribute towards the Digital Decade targets, which set out the EC's vision for Europe's digital transformation by 2030.[4] Connectivity, which is a prerequisite to digitalisation, has also been singled out in the targets. In particular, the targets include the development of gigabit fixed connectivity for all households and provision of 5G in all populated areas.

Enhancing connectivity in rural areas will bring a broad range of benefits that will support the four key pillars that the EC has set out for rural Europe.[5] Digital connectivity will:

- Improve quality of life through access to services such as e-health, digital learning and a broad range of e-government services. The provision of these services digitally will reduce the importance of the proximity to local services and specialists, leading to improvements in both health and education. This in turn should further increase productivity and income levels.
- Enhance economic outcomes by enabling firms to create new products and services, and reshaping how they deliver existing goods and services. Better connectivity in rural areas will also encourage some businesses to relocate to rural communities and enjoy lower input costs. This in turn will help diversify and develop rural economy and decongest urban areas.
- Reduce carbon emissions and slow environmental degradation as it will act as a platform for technologies that can facilitate the circular economy and improve efficient use of scarce inputs. For instance, in Ireland, precision agriculture is estimated to reduce emissions from agriculture by up to 10%.[6]
- Increase social inclusion and wellbeing of those in rural communities as it provides opportunities to participate in economic, social and cultural life. Digital communication tools can help to reduce isolation among more vulnerable citizens and connectivity-enabled benefits in the other areas of the long-term vision, such as higher quality jobs, access to services, or sustainable development can further increase the quality of life in rural areas.

Enhanced connectivity is expected then to fuel the creation of new ecosystems, bring together rural communities, equalise their citizen's access to opportunities and promote greater links with urban areas.

Governments will have to assess the size of the benefits against the costs of rural networks in order to decide the appropriate level and types of support. The benefits will be driven by country-idiosyncratic characteristics of rural areas such as the sectoral backdrop, population density and the starting level of economic and social development in rural areas.

For example, the business needs and the benefits accruing to the German Mittelstand will be different to the Greek hospitality operations and the Spanish agriculture businesses. This report provides a blueprint of how governments could assess the size of the broader benefits arising from enhanced connectivity use cases according to the following, high-level steps:

1. **Market size:** Identify the potential market that could benefit from improved digital connectivity. For instance, the number of businesses in a certain sector or the number of patients with a certain healthcare condition.

2. **Adoption rate:** Estimate the proportion of the market that will adopt and use the digital technology.

3. **Impact:** Assess the impact of the use cases enabled by digital connectivity, for instance increase in the number of quality lived years from digital health solutions, or improvements in productivity from new technology.

4. **Monetisation:** Where necessary, and where appropriate conversion values or shadow prices exist, convert the impact value calculated in step 3 into a financial value, for instance converting CO2 reductions into a financial value using shadow prices. This will allow benefits to be examined relative to the potential costs of increasing coverage levels, and allow governments to understand the social business case for supporting the development of rural networks.

Meeting the Digital Decade targets and delivering these benefits will be challenging and will require significant financial support from governments, particularly in rural areas. The economics in significant parts of rural networks prevent the commercial provision of high-speed and capacity and low-latency connectivity. Low population density in rural areas means that investment needed to cover the remote and rural population is disproportionate. In some countries, the topography such as steep mountains, lack of well-developed non-telecommunications infrastructure, such as roads and electricity grids, as well as planning restrictions, increase the costs of network rollout and maintenance. Finally, the demographics, income levels and existing economic activity in rural areas may translate to low demand for enhanced connectivity products.[7]

These challenges have contributed to the digital divide and connectivity gap between rural and non-rural communities. On average, 86% of all EU households have Next Generation Access (NGA)[8] connections, compared to only 59% of rural households. Addressing this gap will require substantial resources, with additional investment required to provide full 5G coverage and fixed gigabit connectivity across the EU estimated at EUR300bn.[9] In addition, the existing gap varies significantly across countries: Cyprus, Malta and Belgium enjoy near 100% rural NGA coverage, whereas in Finland, Lithuania and Bulgaria it is below 30%. Expanding connectivity in countries with large gaps and significant rural populations in remote regions will require significant investment. For example, Vodafone estimates that to increase 4G coverage in Romania from 65% to 99%, would require c.3,000 additional cell sites.[10] Indeed, in some countries the financial resources required will increase exponentially as coverage approaches the aspirations set by the Digital Decade targets.

Both the benefits and costs will depend on the connectivity technologies and specifications adopted such as speed, capacity and latency. While 5G and fibre-to-the-premises (FTTP) deliver high performance in these dimensions, factors such as low population density and unfavourable topography mean a greater quantity of equipment to deliver benefits is required per subscriber. This makes the trade-off between the benefits and costs of network rollout more acute in rural areas. As such, some national governments are exploring alternative technologies such as Fixed Wireless Access (FWA), which may lower deployment costs relative to FTTP by up to 40%.[11]

However, these alternative technologies also come with the same trade-offs. In the case of FWA, increasing coverage with the technology requires a reduction in the capacities and speeds that can be offered.

European governments have a unique opportunity to kick-start the regeneration of their rural regions by enhancing connectivity through the funds provided by the RRF. Although the allocation of public funds is necessary, this can be complemented by wider packages of policies to encourage collaboration between industry and government in order to close the connectivity gap. Policies considered or put in place in some countries include public-private partnerships, the simplification of the permit application process, infrastructure sharing agreements, and ensuring spectrum licensing and allocation mechanisms achieve efficient spectrum allocation. In addition, to fully realise the benefits of connectivity, investment in complementary initiatives will be required. Such initiatives would be targeted to overcome barriers to digital adoption, such as a lack of digital skills and by expanding non-telecommunications infrastructure. National governments, in consultation with the industry, will have to decide on the right mix of policies that can accelerate connectivity, and thus rural regeneration, given the country specific context.

Contents

Introduction

Rural areas in the European Union (EU)

Rural areas are of great significance to the EU and its member states. They cover 83% of the bloc's land area and rural communities are home to 30% of the total EU population (c.220 million citizens).[12] They are the source of key ecosystem services, providing communities with the food and water they consume, and industry with raw materials. They are also home to the natural ecosystems and biodiversity that are key to delivering greater sustainability, as well as health and social benefits.

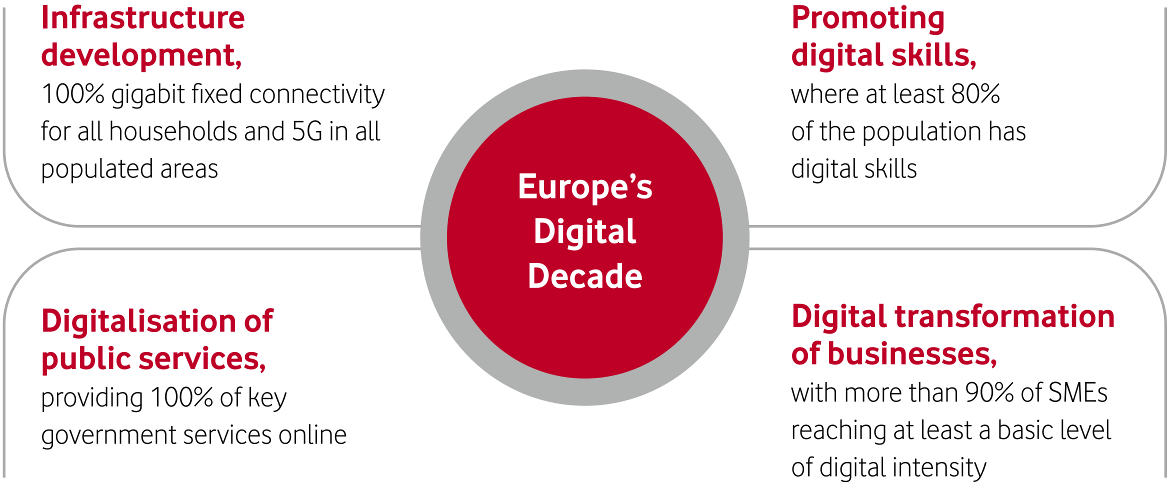
Rural development is a priority for the EU, being the second pillar of the common agricultural policy, which represents around a third of the total EU budget.[13] The European Commission (EC) is currently developing its long-term vision for vibrant, connected and sustainable rural areas by 2040. The vision's objectives are to strengthen the presence of rural areas in Europe, and address their unique challenges relating to demographic change, digital connectivity, low income levels and limited access to services.[14]

Realising the potential of rural communities is essential for promoting a sustainable future, reducing inequalities and encouraging social cohesion between and within member states. Supporting citizens and businesses in rural areas can further significantly contribute to the achievement of wider EU objectives, including the twin green and digital transitions, reinforcing the economy and promoting a fair and tolerant society.[15]

Europe’s digital ambitions

In parallel to its long-term vision for rural areas, the EC has set out its vision for Europe’s digital transformation over the coming decade in the Digital Compass, which aims to promote digitalisation of the EU across infrastructure, skills, business and government.[16] These ‘Digital Decade’ targets include ambitious objectives to deliver enhanced connectivity: for all households to have a gigabit connection and for 5G to cover all populated areas by 2030. This is a step-change from the previous digital agenda targets that aimed for at least 100 Mbps for all households, and 5G in all urban areas and major roads and railways.[17]

Figure 1: Digital decade targets



Investment in digital technologies and connectivity has long been identified as an enabler of socio-economic progress and a prerequisite to promoting a digital society. The EU’s Digital Economy and Society Index (DESI) highlights this[18] and some member states now consider connectivity as a social right.[19]

Building on this, enhanced connectivity is expected to be transformative, due to the low latency and high capacity and speeds that are enabled. The above targets are therefore expected to drive Europe’s digital transformation by enabling the creation of ecosystems and new use cases that have the potential to transform industrial sectors, public services, people’s consumption of media, and to drive to a more sustainable world.[20]

The need to deliver on this digital agenda has been further highlighted by the COVID crisis. Connectivity has enabled economies and societies to be as resilient as could be expected to this global health crisis, with citizens depending on digital connectivity for remote working, schooling, health support and interactions with friends and family.[21] The average proportion of employees working remotely has increased from 9% to 64% during the pandemic and is expected to be at around 40% by 2025.[22]

In line with this, the EU is investing a proportion of the EUR 1.8 trillion assigned to the Multiannual Financial Framework and the NextGenerationEU Fund into supporting the digital transformation. For instance, a minimum of 20% of the Rescue and Resilience Facility (RRF) is being allocated to digitalisation, with planned allocations of funds to digital projects varying by member states. Member states have submitted their national plans for investment of the RFF to the EC, which will be assessed by the EC and approved by the European Council.[23]

Connectivity in rural areas

The EU's digital ambitions risk being constrained by the digital divide that exists between urban and rural areas in the EU. Currently, 41% of EU rural households do not have access to high-speed internet access compared to only 14% across the whole of the EU.[24] 5G deployments are also currently concentrated in urban areas with many member states lacking plans for rollout into rural areas.[25]

Significant investment will be needed to enhance and expand rural connectivity in order to close the gap and achieve the ambitious coverage targets set out in the Digital Decade. The European Investment Bank (EIB) has identified an investment gap against the existing targets for communication networks of EUR 42bn per year.[26] The economics of deploying networks in rural areas are already challenging and will become even more so in order to deliver gigabit and 5G connectivity to rural communities.

Due to these challenges, there is a risk across Europe that sufficient and effective support is not provided to ensure enhanced connectivity is made available in rural communities. This then risks reinforcing existing digital divides, if rural communities do not have access to the connectivity required to participate in an increasingly digital society.

This report

Given the current process of allocating funding from the EU RRF budget and member states, national plans, now is the time for European governments at many levels to appropriately assess how best to support rural digitalisation. This requires an understanding of the socio-economic benefits of rural connectivity and the costs and challenges in deploying enhanced connectivity in rural areas, as well as appropriate policies that can realise the benefits and achieve enhanced connectivity in rural areas.

This report is intended to provide policymakers with tools to support them in their assessment of cases for intervention and support for rural digitalisation. It has been informed by a review of relevant literature and research, as well as interviews with European government stakeholders. The remainder of the report is structured as follows:

- Second section articulates the mechanisms by which digital connectivity can promote the vision for rural Europe and sets out the frameworks which governments can use to assess the size of the wider socio-economic benefits of enhanced rural connectivity;
- Third section examines the costs, cost drivers and challenges associated with developing mobile and fixed networks in rural areas, as well as alternative network technologies that could overcome these barriers; and
- Fourth section consolidates the policy options available to governments to help improve digital connectivity in rural areas, including partnerships with local authorities and operators, as well as complementary initiatives.

Connectivity as an enabler of rural communities

Expansion and enhancement of digital connectivity in rural areas are key components to delivering the EC's Digital Decade ambitions and its long-term vision for rural areas. This is widely recognised and support for developing rural connectivity is being made available at the regional, member state and EU-wide level (i.e. the RRF).

Rural digitalisation, enabled by better rural connectivity, will bring a broad range of benefits. Digital transformation will support new ecosystems to develop across rural industries, based on innovative technological use cases leveraging the low latency, reliability, high capacity and high speeds delivered through gigabit and 5G networks. It will also enable improved quality of life in rural communities, with more flexibility in where people live and work, services that are delivered more innovatively and cost-effectively, more tools to enhance social inclusion, increased productivity and more sustainably delivered growth.

In particular, key benefits of rural digitalisation align to the four key areas for rural development identified in the EC's public consultation on the long-term vision for rural:[27]

- **Income and employment:** Creating innovative rural areas by supporting SMEs and rural entrepreneurship that can drive income and employment opportunities.

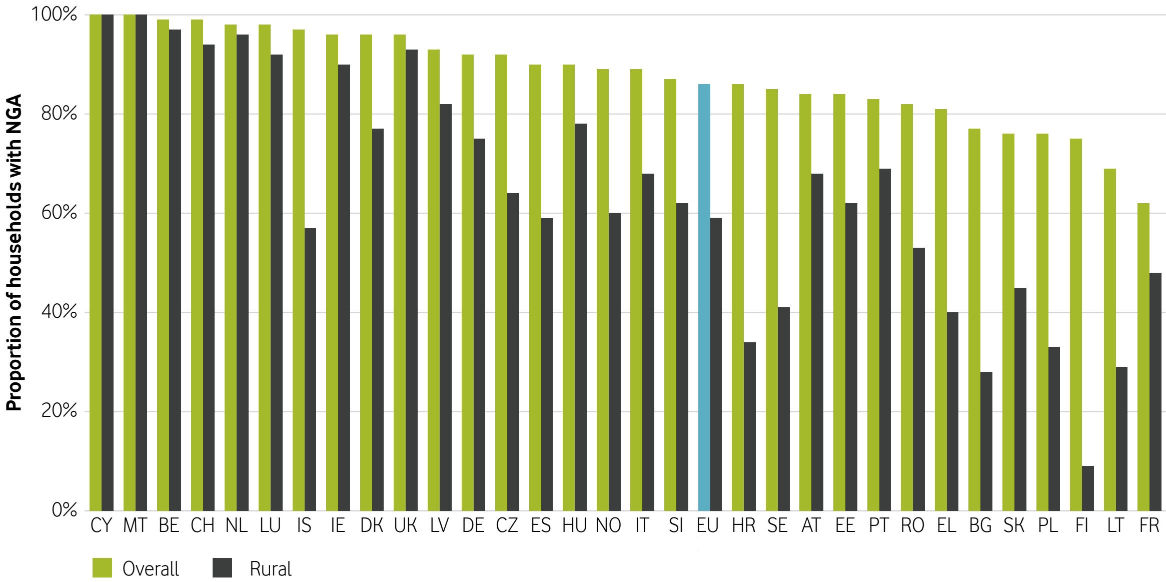
- **Environment and climate change:** Creating a low carbon economy by decoupling economic growth from resource usage.

- **Infrastructure and services:** Creating vibrant rural communities by ensuring access to, and high quality of, basic services such as health, education and transport, with infrastructure being a key enabler.

- **Social inclusion:** Creating a society that does not leave anyone behind by providing opportunities to participate fully in economic, social and cultural life.

The extent of the benefits of rural digitalisation will depend on specific country and rural factors, which vary across and within member states. These factors include demographics, the composition of businesses in rural areas across dimensions such as sector and size, the availability of public services and the current level of connectivity. For example, while the proportion of households with access to NGA networks is generally lower in rural communities, the size of the gap between rural and urban areas varies substantially by country, as shown in Figure 2.

Figure 2: Rollout of NGA in EU countries, 2019



Source: DESI

For national and regional governments to effectively support rural connectivity and consider country-specific factors, policymakers require robust and tailored assessments of the size and types of benefits that can be expected. Therefore, this section of the report sets out a simple framework to achieve this following four distinct steps taking into account a country's or region's idiosyncrasies:

1. **Market size:** Identify the potential market that could benefit from improved digital connectivity. For instance, the number of businesses in a certain sector or the number of patients with a certain healthcare condition.

2. **Adoption rate:** Estimate the proportion of the market that will adopt and use the digital technology.

3. **Impact:** Assess the impact of the use cases enabled by digital connectivity, for instance increase in the number of quality life years from digital health solutions, or improvements in productivity from new technology.

4. **Monetisation:** Where necessary, and appropriate shadow prices exist, convert the impact value calculated in step 3 into a financial value, for instance converting CO_2 reductions into a financial value using shadow prices. This will allow benefits to be examined relative to the potential costs of increasing coverage levels and allow governments to understand the social business case for supporting the development of rural networks.

The following sub-sections outline the main type of benefits arising from expanded and enhanced connectivity within the areas identified in the long-term vision for rural communities. The transmission channels by which expanded and enhanced connectivity deliver these outcomes are discussed then and the above framework is then applied to provide a blueprint for governments on how to assess the size of these benefits.

The benefits set out in these areas represent the key benefits that have been identified from the literature and interviews with government officials. However, enhanced connectivity could deliver broader benefits and foster digital ecosystems that cannot be predicted based on current trends. Due to this, policymakers may wish to consider other benefits as important digital technologies and use cases become more developed.

Key findings from interviews with government stakeholders:

As part of this report, informal interviews with stakeholders from Ministries of the Economy, Transport and Communications across a small set of European governments were conducted to understand which benefits of rural connectivity have been considered in the decision-making process of infrastructure rollout. The following provides an overview of the key learnings:

- **Importance of high-speed connectivity:** Representatives considered enhanced connectivity as an important enabler to address the digital divide within countries and to promote the attractiveness of rural areas by increasing living standards. For instance, some government stakeholders considered connectivity as a social right, where equal access to high-speed internet should be ensured nationwide. This is reflected in European citizens' attitudes, with respondents to a recent survey highlighting a good internet connection as the most important condition in considering a move to the countryside.[28]

- **Benefits of rural connectivity:** Government stakeholders consider connectivity as an enabler to increase economic activity in rural areas. For instance, productivity gains and job opportunities have been stated as the key benefit of rural connectivity. In addition, wider benefits such as health, education, mobility and the environment were also considered to be important.

- **Quantification of benefits:** With the exception of one out of seven interviews with European government stakeholders, representatives were not aware of studies that had quantified the broader benefits of rural connectivity. The lack of data availability and methodology to conduct a robust cost-benefit analysis has been noted as a key concern. However, some mentioned that the quantification of the benefits will be essential to make policy decisions and to justify the high investment costs of increased coverage.

- **High-speed connectivity as a step-change:** Representatives considered 5G and gigabit networks as potential enablers of a step-change in innovation and ecosystem development. Also, most agreed that it is important to rollout the infrastructure to rural communities even before the innovative use cases become apparent, in order to avoid widening of the digital divide between urban and rural.

- **Policy considerations:** Public-private partnerships that set a clear objective and involve industry stakeholders in the decision-making process were mentioned as a key component to ensure a successful infrastructure rollout. The reduction of administrational burden to simplify and speed up the permit application process for operators has been highlighted as another important policy. It was further suggested that infrastructure sharing agreements to reduce costs can be effective, and that the usage of the EU Connectivity toolbox as a guidance for the rollout of fast broadband and 5G is a useful framework.

- **Complementarity policies:** In addition to policies that support the rollout of high-speed connectivity, it was suggested that initiatives targeted to overcome other barriers to digital adoption, such as improving digital skills and expanding non-telecommunications infrastructure could be needed. Some member states have introduced vocational programs in rural areas to increase the take-up of digital technologies enabled by high-speed connectivity.

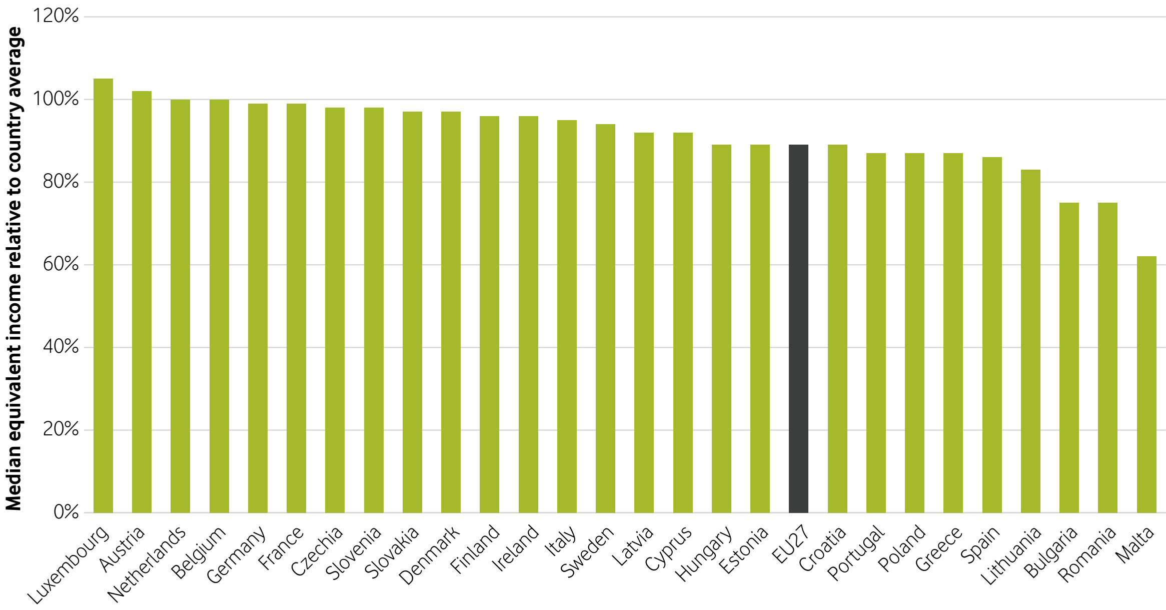
Income and Employment

Income and employment in rural areas

The EU envisions thriving rural communities that can attract and develop innovative businesses and use the full potential of talent in those areas. For this reason, one of the key components of the long-term vision for rural Europe is a strategy to create jobs and support rural entrepreneurship and innovation. Supporting small and medium-sized enterprises (SMEs) will be important when addressing disparities between rural and urban areas, as they play a key role in rural economies. SMEs account for 75% of employment in rural areas,[29] compared with an average of 67% for the EU.[30] Supporting SMEs in line with the EU strategy to increase SME capacity, technology usage, market access and participation in global value chains will therefore be crucial for the development of rural areas.[31] In turn, improvements in the number and quality of jobs can help reduce the migration of educated high-skilled workers from rural to urban areas (brain-drain).

However, income levels in rural communities are lower on average than in rural communities. For instance, the median equivalized income[32] in rural communities was only 89% of the EU average income. On average, people in rural communities earn around EUR 2,700 less per year compared to those in urban areas.[33] As Figure 3 shows, this gap varies across member states. As part of the EC's public consultation on the vision for rural areas, almost 70% of EU citizens responding to the consultation indicated that quality job opportunities are not sufficiently available for people living in rural areas.[34]

Figure 3: Rural median equivalent incomes compared to the country median, 2018[35]



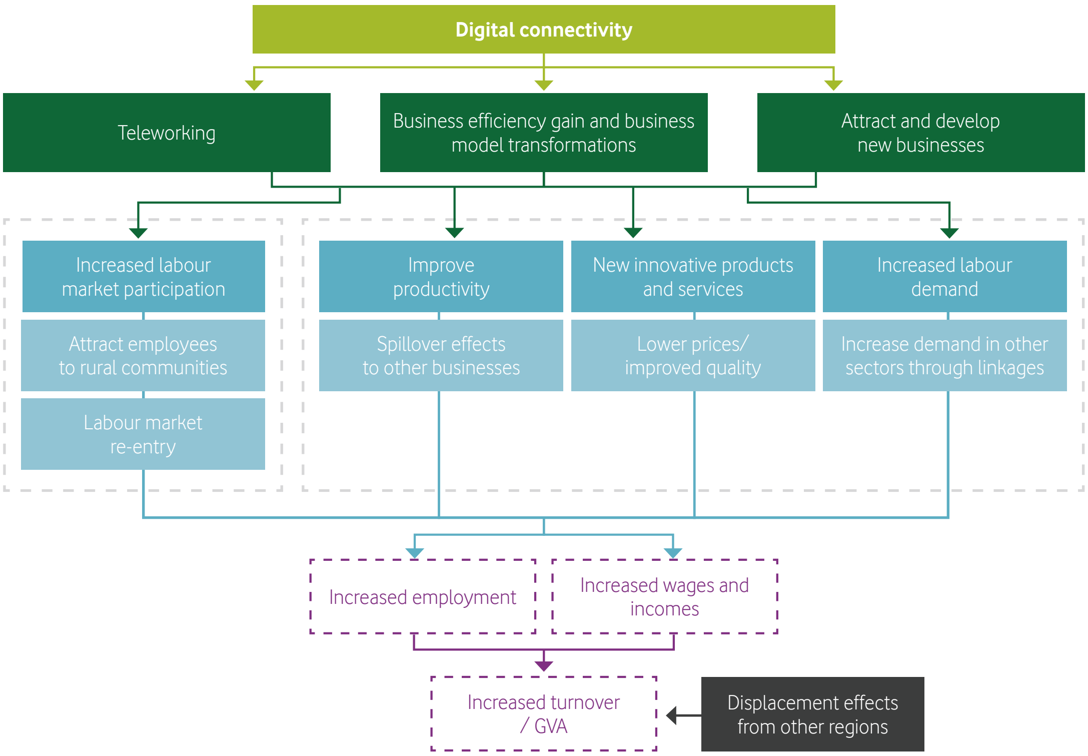
Source: Eurostat, Malta values using 2016 data

Income disparities are partly driven by the dependence of some rural economies on agriculture and tourism, in which there is a higher propensity for seasonal work than in other sectors.[36]

The benefits of connectivity to income and employment

Enhanced connectivity can foster income and employment opportunities by improving the labour market through remote working and better job matching. It can also foster the productivity of businesses through the digitalisation of processes, which can further promote the availability of high-quality jobs and increase the labour demand in rural areas. Research by the Federation of Small Businesses found that 94% of small business owners rate a reliable broadband connection as critical to the success of their business.[37] Increasingly, enhanced digital connectivity is seen as essential infrastructure in order to attract and develop businesses and talent. It can also help mitigate some of the challenges faced in rural communities, such as low productivity or seasonal work and help stem the brain-drain. A previous Deloitte study found that SMEs that use data-driven innovations were able to increase their productivity by 8.9%.[38] Figure 4 shows the transmission mechanism through which digital connectivity can enable higher income and employment in rural areas.

Figure 4: Transmission mechanisms through which digital connectivity can promote rural economies



Business efficiency gain and business model transformations: Digital connectivity can increase the productivity of rural businesses by allowing them to innovate and offer new services.[39] Enhanced digital connectivity can promote the adoption of new technologies and services such as smart logistics, precision agriculture, augmented and virtual reality applications or automated processes. For example, augmented reality applications using a digital platform could promote the tourism industry in rural areas by allowing users to virtually visit historical and cultural places and provide training content for people working in the tourism sector.[40] In the agricultural sector, the mass deployment of Internet of Things (IoT) sensors could enable smart farming, increasing the productivity of farm holders through resource efficiencies.[41]

For instance, smart farms enabled by digital connectivity, have led to productivity gains and cost reductions of EUR 8,700 per farm[42] and promoted high-tech jobs in Ireland.[43]

Digital connectivity will be essential in promoting the use of cloud services to store and analyse a large amount of data to enable smart IoT solutions.[44] Businesses will need reliable high-speed fibre or 5G mobile networks with low latency to be able to access data in a timely and secure manner. Connectivity can further enable local businesses to use cloud services for increased collaboration and better respond to the market. These technologies will allow rural businesses to offer higher quality or more competitively priced products and services, allowing their businesses to grow.

Similarly, digital connectivity can increase access to non-rural markets, which may traditionally be inaccessible due to the long distances between rural businesses and consumers. Digital connectivity can also enable businesses to better manage the whole customer lifecycle and deliver better quality and more personalised products and services, increasing businesses' competitiveness and allowing them to grow.

While technology can displace some jobs, greater product demand and increased labour productivity can increase levels of employment and provide higher income jobs. This can create spillovers into the rest of the rural economy as other businesses can learn and adapt similar technologies. This can increase the demand for products and services and further increase employment levels and incomes. A review of the high-speed connectivity in the UK found that turnover per worker increased by more than 3% for businesses accessing speeds over 200Mbit/s.[45]

Attract and develop new businesses: As digital connectivity enables productivity gains, it will increasingly be considered as essential infrastructure in firms' decisions on where to locate. While enhanced connectivity enables existing local businesses, such as those in agritourism, to grow, it can also support the development of other sectors in these areas, supporting the diversification of rural economies. New technologies enabled through high-speed and low latency networks will create new business opportunities that can improve the resilience of rural communities and promote work and incomes that are not seasonal in nature. Evidence from the superfast broadband subsidy in the UK found that the presence of superfast broadband increases the number of firms located in an area by 0.3%.[46] Evidence from France suggests these benefits are mainly accrued by the services sector and new micro businesses in rural communities.[47]

Teleworking: Due to the greater distances and poorer transportation networks, those in rural communities face longer and more arduous commutes to work. This can restrict the pool of workers available to local employers, leading to a mismatch in skills, limiting opportunities and leading to people leaving the labour force. Remote working can help resolve these challenges and lead to several benefits for rural communities:

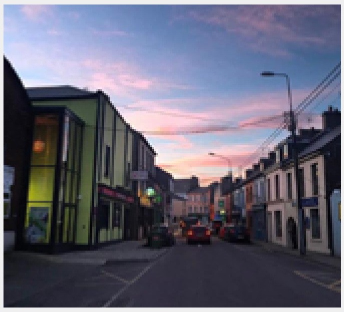
- Firstly, remote working can lead to improvements in productivity with less time spent commuting, fewer work distractions and less absenteeism.[48]

- Remote working can also improve labour market matching in rural communities as employers and employees are not limited to those geographically contiguous to them, giving employers and employees greater choice. Furthermore, digital connectivity allows for greater sharing of information between employer and employee that can also reduce labour market frictions. According to the McKinsey Global Institute, online talent platforms could boost global GDP by 2% by 2025, while increasing employment by 72 million full-time-equivalent positions. In Norway, digital connectivity led to improved labour market matching and was found to reduce the steady state unemployment rate by one-fifth, as vacancies were filled faster and periods of unemployment were lower.[49]

- Remote working can further help certain social groups such as the elderly or women back into work, expanding the labour force.[50] It can allow these groups the flexibility to work around other commitments such as caring for children or vulnerable people and so enable them to increase their hours of paid work.[51] Remote working could therefore also help to decrease the gender gap in employment as this is three percentage points greater in rural EU communities.[52]

- Remote working can help retain and attract talent to rural communities, as people's locations become less important to their jobs. While this may lead to some displacement of benefits (i.e. benefits shifting from urban to rural areas), people also enjoy greater choice in where to live, which can be determined more by their personal preferences and less by their work location. For instance, the Irish Rural Future Plan aims to invest significantly in remote working infrastructure to provide an opportunity for people to stay in rural communities, while following their career ambitions and to attract people to move from urban to rural areas.[53]

Case study example: The Ludgate digital hub



A joint venture between Vodafone and ESB led to the rollout of FTTP in the town of Skibbereen, and to the Ludgate hub, creating Ireland's first digital hub. The hub created an entrepreneurial ecosystem which promotes opportunities for new businesses by enabling peer to peer learning, skills sharing and virtual mentoring.

In 2018 the Ludgate digital hub attracted 21 businesses, created 92 jobs, attracted families to move there, and led to a EUR 4.2 million boost to the local economy. It aims to eventually support 500 jobs directly, and an additional 1,000 jobs indirectly.

The platform eStreet, Ireland's first fully inclusive eCommerce community portal, was created as part of the programme which enabled 11 local retailers to sell their products online and access new markets.

The hub also promoted digital skills through delivering coding classes to 16 and 17 year olds and promoted community partnerships by supporting 15 community groups.

Source: Vodafone (2021); European Network for Rural Development (2017)

Measuring income and employment benefits

The economic benefits of digital connectivity in rural areas are seen as key to overall rural development by policymakers and are delivered through several different channels. Analysis should be guided by which channels are more measurable and tractable. Therefore, a benefits assessment may focus on higher productivity and improved labour market matching, rather than other channels, such as the development of new ecosystems and the potential relocation effect of businesses and employment.

To measure these benefits, some studies assess the impact of connectivity at the macroeconomic level, using econometrics to estimate impact on GDP or GDP per capita.[54] However, these studies are generally undertaken on aggregated country datasets, measuring the impact on the whole economy rather than on specific regions or areas.

The framework described in Figure 5, which follows the structure set out at the beginning of this section, outlines a micro-level approach to assessing the benefits in rural areas, which is needed to understand how to prioritise rural connectivity. As highlighted above, this focusses on productivity and employment benefits of rural connectivity and does not cover benefits that entail a greater level of uncertainty, such as new ecosystem development. However, the framework can be applied to future use cases and ecosystems as these emerge.

Figure 5: Measurement framework for economic benefits

	Market size of use case	Adoption rate	Impact	Monetization
Method	The market size can be determined by the population of interest for a specific use case. National statistic agencies are likely to be able to provide this data. For example: • Number of businesses and characteristics such as size, industry and GVA by sector based on Standard Industrial Classification codes. • Percentage of teleworking-eligible jobs for each industry. • Proportion of people who could re-enter the labour force due to teleworking opportunities based on population statistics or surveys, including future of work surveys.	The adoption rate reflects the willingness to take-up a specific use case and could be based on local surveys or use cases from urban areas, other countries or similar technologies. For example: • Estimates on the number of businesses that could and would be willing to move to rural communities. • Willingness to take up technologies of businesses and employees in rural areas (by size, industry, demographics of employees) • Proportion of people who would be willing to take-up teleworking.	The impact can be quantified by conducting an analysis on benefits where networks have already been developed. Alternatively, surveys or use cases from urban areas or other countries could be used to inform assumptions. For example: • **Incomes:** Estimating increases in business turnover provides an estimate of total increases in incomes (some of which will be shared with workers). • **GVA:** Evidence of the impact of digital connectivity on enhancing productivity measured as GVA or turnover per worker. • **Reductions in unemployment:** Estimates of reduction in those claiming unemployment benefits	Financial values can be applied to outcomes that do not have a monetary value should robust shadow prices or methodologies be available. For example: • **Incomes:** This will already be a financial value and will account for increases in productivity, firm relocation and increases in employment. • **GVA:** Apply the estimated increase in GVA per worker to the number of firms and employees per business to calculate total improvements in economic benefit • **Reductions in unemployment:** Apply annual salary estimates to the number now employed.

Benefit specific considerations

Given the diverse characteristics of EU member states, governments will have to consider how the inputs for adoption rates and impact will vary based on country specific factors, for instance:

- **Business characteristics:** Governments have to consider that the adoption rate of technologies will vary depending on characteristics such as size of businesses as this can influence the level of digital skills and available capital of a business. Similarly the impact of technology on improving productivity and enabling teleworking will vary by industry groups. For example, countries such as the Netherlands where c.48% of the population is employed in the financial services industry or public sector may be able to provide more teleworking opportunities compared to other countries that rely more heavily on the manufacturing or construction industry such as Slovakia.
- **Location attractiveness:** The propensity of firms and employees to relocate will depend on other factors, such as other available infrastructure, and levels of education, which will impact the relative competitiveness and attractiveness of an area.
- **Labour market:** Labour market matching could have a more significant impact in countries with greater existing labour market frictions and search costs. Additionally, rural communities are only likely to benefit from improved access to labour markets if rural employees have the necessary skills to match with employers.
- **Regional and national impacts:** Productivity and employment benefits can be measured for the whole economy of a country or on a regional level. This will depend on the specific business case and will be subjective for different governments.
- **Displacement effects:** When assessing benefits on a national level, it is important to consider displacement effects as the growth of businesses in rural areas, and the relocation of businesses to these communities will at least in part come at the cost of other locations. A conservative estimate could only consider the productivity and employment benefits of existing firms in rural communities.
- **Distributional weightings:** A higher social value can be given to an increase in earnings of lower income households based on the principle of diminishing marginal utility of income. This will be subjective and relevant for different governments. The UK Greenbook provides an estimate of the marginal utility of income at 1.3 for distributional weightings based on established literature.

Examples

- The superfast broadband subsidy in the UK found that high-speed broadband connection increases the number of firms located in an area by around 0.3%.
- Based on the existing literature, a PWC study has identified that between 3.5% and 7.5% of unemployed people could be helped to find a workplace if they became digitally included.
- The BDUK found that the availability of high-speed broadband raised the turnover of workers by 0.38%, equivalent to £1,390 in GVA per firm per year. It is estimated that the programme led to a net increase in national economic.

Outcomes should be presented in Net Present Values (NPV) using an appropriate discount rate.

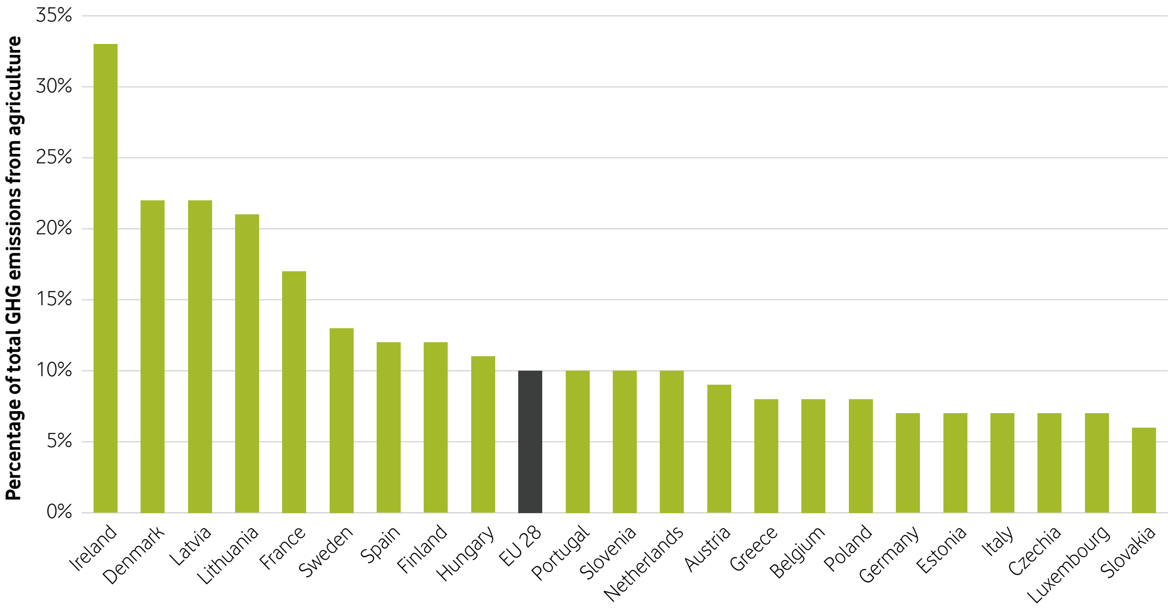
Environment and Climate change

Environment and Climate change in rural areas

Rural areas are a critical part of the European green transition. Improvements in the management of natural resources and the mitigation of climate change will be driven by rural areas as many ecosystem services such as food, feed and raw materials are produced in these areas. In addition, the economies of many rural areas rely largely on the agriculture sector, transformation of which will be key to tackling climate change.

For instance, the EU Green Deal highlights the importance that sustainable agricultural production will have in achieving carbon net zero by 2050. In 2018, agriculture accounted for 10% of EU28 greenhouse gas (GHG) emissions, varying by country as shown in Figure 6.[55] Agriculture is also responsible for other pollutants that can damage health and natural ecosystems, with more than 40% of EU rivers and coastal water bodies affected by diffuse pollution from agriculture.[56]

Figure 6: GHG emissions from agriculture by EU country, 2018[57]



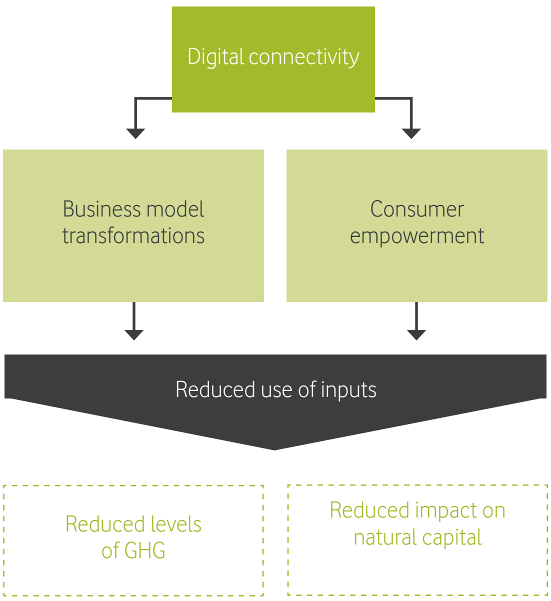
Source: OECD

The CAP for 2021-2027 highlights the role of the digital transformation in facilitating a sustainable and competitive agricultural sector, enabling vibrant rural areas with a focus on climate change and a fair income for farmers.[58]

The benefits of connectivity to the environment and climate change

Digital technologies can lead to improvements in efficiency or transform business models, leading to reductions in input requirements, cuts to emissions and promotion of the circular economy. Smart solutions will leverage technology such as IoT, Machine Learning and Big Data to develop and commercialise new applications that support greater efficiency. However, these technologies will all require fast, secure and reliable connectivity to gather and process data, making gigabit and 5G network deployments imperative to achieving greater sustainability.

Figure 7: Transmission mechanisms through which digital connectivity can promote sustainability



Given agriculture's significance as a source of GHG emissions and use of natural resources, the ability of farmers to adopt smart technology will be essential in improving environmental impact. For example, machine guidance and controlled traffic farming can reduce fuel use by 6-25% depending on the specific use case, further resulting in reduced soil compaction and erosion.[59,60] A case study on maize production in Germany has shown that variable rate applications technologies (VRT) to improve fertilizer usage led to a reduction of nitrous oxide (N_2O) emissions of 34%.[61] More broadly, rural areas are witnessing a reduced dependence on primary sector activities and the emergence of a more diversified economy across other sectors, driven by technology and connectivity. It will be important that these sectors can grow in a sustainable way using the latest green and digital technologies.

Moreover, digital technologies connect value chains together across a whole economy to provide better quality information to empower economic actors, including citizens, businesses and governments to embed sustainability in their decision making. For example, a study from the European Commission has found that smart meters can lead to energy savings of 2-10%.[62] This allows producers based in rural areas, as well as elsewhere, to optimise production and minimise their environmental impact.

Digital connectivity can enable environmental benefits in two additional ways. New digital technologies are more efficient in themselves. 5G networks are more energy efficient[63] and fibre relies on fewer intermediate devices and amplifiers requiring less power.[64] Therefore, accelerating the shift to these networks from legacy generation technologies may have a positive impact on energy usage.[65] These emissions savings could be relatively higher in rural communities, which need relatively more intermediate devices and amplifiers to cover greater distances. In addition, the adoption of teleworking could further help to reduce GHG emissions by reducing commuting time.

For example, it is estimated that teleworking in Germany has the potential to save GHG emissions of 12 Mt CO_2e annually, equivalent to 83 million passenger flights from London to Berlin.[66] In addition, a study in France found that an average of 2.9 days of remote working per week could reduce the environmental impact of commuting by about 30%, accounting for 3.7% of GHG emissions. This is equivalent to a reduction of 0.5% of overall GHG emissions.[67]

Smart agriculture

5G will enable the use of a large number of IoT sensors in crops and herds, and allow for low latency innovations such as automated tractors. Precision agriculture can allow farmers to monitor and manage their crops and livestock with greater accuracy, and collect more data enabling efficiency gains. Evidence from the National Broadband Plan (NBP) in Ireland suggests GHG emissions have fallen by 10% per farm.

Inputs	Processing, manufacture and assembly	Storage and logistics	Managing consumption
Smart sensors will improve the accuracy with which farmers can monitor their crops, and automated drones can place inputs such as fertiliser accurately. This will enable more efficient use of key inputs such as water and fertiliser.	Smart tractors can improve the efficiency of harvests and ensure all crops are collected before they rot and give off GHGs	Smart labelling and IoT sensors can reduce the risk of food spoilage during transport and storage	Increased consumer awareness about food sources and the environmental costs of meat and dairy

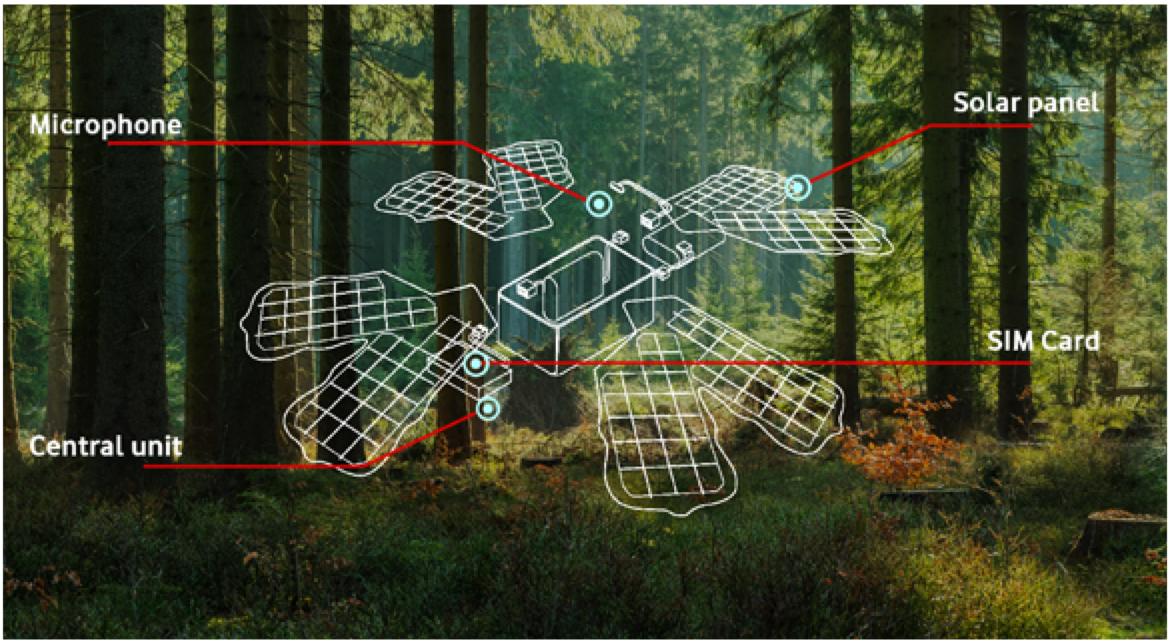
While precision agriculture technologies can increase efficiencies in farming, the production of equipment such as sensors and the processing of data consumes energy. This should be considered when measuring the net environmental benefits of a technology.

Source: PwC - NBP Benefit Report (2019)

Smart forests

Vodafone has developed a smart forest in Covasna County, Romania. The system consists of a series of devices called "digital guardians", equipped with acoustic sensors, that capture a wide range of sounds from the environment which are analysed in real-time and, if noises such as chainsaws, cars etc. are detected that could indicate possible suspicious activities, an alert is sent to a forest manager. A single device has a coverage radius of 1km and can prevent the deforestation of over 3km^2 of forest.

Source: Vodafone; Business Review (2021)



Framework for measuring environmental benefits

Measuring environmental and sustainability impacts is increasingly important to public investment cases and policy evaluations, given governments' green commitments. Several studies estimate the environmental benefits of improved connectivity from particular use cases, most prominently teleworking and business travel,[68] as well as cloud computing, dematerialisation and e-commerce.[69] However, few studies provide a monetary valuation of these benefits. Furthermore, there is minimal discussion in the literature about how digital connectivity can improve natural capital. The potential for digital connectivity to improve natural capital could be large in rural communities due to the prevalence of agriculture in rural communities. The extent of environmental benefits is likely to depend on country-specific factors such as the current fuel mix of a country or the size of businesses and farms within the region, varying across Europe.

As economic actors continue to adopt new technologies and digital connectivity enables new ecosystems, the potential benefits from digital connectivity on the environment and ecosystems will rise. The framework below sets out how these benefits can be first quantified in terms of reduced negative effects (lower emissions, less land pollution), which can then be assigned shadow prices to estimate a financial value.

While the framework provides an approach to measure the impact of a technology use case on the environment, policymakers may also consider the environmental impact of technology usage itself in order to better understand the net benefits. For example, equipment such as IoT devices requires the mining and extraction of raw materials that emits GHG emissions and can lead to increased e-waste.[70] In addition, data processing and storage on cloud services are a growing source of emissions.[71]

Figure 8: Framework for measuring environmental benefits from reductions in greenhouse gas emissions and improvements in natural capital

Method

Market size of use case

The market size can be determined by the population of interest for a specific use case. National statistic agencies are likely to be able to provide this data. For example:

- Number of small, medium and large farm holders in the area based on national statistics.
- Number of businesses by size and industry.
- Number of jobs that are "teleworking-eligible" in the area based on Standard Industry Classifications (SIC).

Adoption rate

The adoption rate reflects the willingness to take-up a specific use case and could be based on local surveys or use cases from urban areas, other countries or similar technologies. For example:

- Willingness and affordability to adopt technologies amongst local farms (by size).
- Estimating the number of local businesses that would take up technologies (by size and industry).
- Proportion of people willing to take-up teleworking

Impact

The impact can be quantified by conducting an analysis on benefits where networks have already been developed. Alternatively, surveys or use cases from urban areas or other countries could be used to inform assumptions. For example:

- **Energy:** Quantify energy use or efficiency by measuring fuel / energy consumption saved per year, broken down by fuel type where possible.
- **Inputs:** Quantify the reduction of inputs such as fertilizer usage per year.
- **Emissions:** Convert energy, fuel or input reduction changes into GHG emissions by using CO2 emission coefficients by fuel type (provided by the International Energy Agency, EIA)
- **Natural Capital:** Quantify changes to natural capital, including the required amount of natural resources, from changes in different inputs.

Monetization

Financial values can be applied to outcomes that do not have a monetary value should robust shadow prices or methodologies be available. For example:

- **Emissions:** Apply a carbon value to the reduction of CO2 emissions to estimate the financial value
- For example, using values form the EU Emission Trading System or "shadow carbon prices" that consider the cost to society.
- **Natural Capital:** The financial value of natural capital can be based on values from the UN SEEA accounts or on willingness-to-pay (WTP) studies.

Benefit specific considerations

Given the diverse characteristics of EU member states, governments will have to consider how the inputs for adoption rates and impact will vary based on country specific factors, for instance:

- **Environmental policies:** The adoption rate could be lower in regions with smaller businesses / farms due to the fixed costs of those technologies and a potential lower digital literacy rate. Adoption rates are also likely to increase over time as government environmental policies become stricter and the cost to pollute increases.
- **Business characteristics:** The adoption of precision agriculture technologies are likely to be greater in countries with larger farms, such as France, due to the fixed costs of these technologies. Furthermore large farms are more capital intensive, and so could benefit more from the input efficiencies enabled by precision agriculture.
- **Cultural characteristics:** The perception of some technologies such as teleworking may differ between countries, and the extent of the impact could further depend on the type of commuting (e.g. train, cars).
- **Fuel mix:** Environmental benefits are likely to be greater for countries that rely more on dirtier fuels such as coal or oil. Furthermore, the extent of environmental benefits of teleworking depend on home versus office energy consumption.
- **Demand characteristics:** Consumers in some countries or regions are more willing to support sustainable and green businesses compared to others, and are therefore more likely to place a higher value on natural capital and emissions reductions.

Examples

- A study by the Carbon Trust estimated the emissions savings of homeworking, based on the number of teleworkable jobs across several European countries. It found that annual GHG savings from homeworking could be as high as 12.2 Mt CO2e in Germany and 8.7 Mt CO2e in Italy, equivalent to 83 million and 60 million London to Berlin passenger flights.
- A study from the European Commission (2019) has found that that precision agriculture technologies can reduce fuel usage by 2.8-5.4%, and reduce fertiliser usage by up to 8%. The study estimated that the large-scale application of precision farming technologies in the EU could lead to a reduction of up to 6567 kt CO2e per year, which represents around 1.5% of the total EU 2015 GHG emissions of the Agricultural sector.
- Greenpeace has estimated that one additional day of working per week from home in Germany could save up to 2.8m tCO2e, equivalent to 11% emission savings from commuter travel and 2% from passenger travel in Germany.
- The UK has established carbon value assumptions for the traded (sectors covered by ETS) and non-traded sector for a low, central, and high scenario.
- The European Bank for Reconstruction and Development (EBRD) uses "shadow carbon prices", suggesting a price of US$40-80 / tCo2 in 2020 in line with the High-Level Commission on Carbon Prices.

When measuring environmental impacts, direct and indirect rebound effects should be taken into account.

Public services

Public services in rural areas

Strong healthcare and education systems, higher levels of digital skills, and the transformation of mobility will be essential in delivering the vision of a more sustainable, resilient Europe that is well-equipped for the digital and green transformation.

Depopulation of rural areas, with younger generations moving to cities, and the resulting demographics towards an ageing and more vulnerable population requires governments to increase resource commitments to maintain services. A lack of access to those services and lower levels of education can exacerbate the difficulties faced by those in rural communities and increase the risk of poverty, poorer health, and lower levels of wellbeing.

In particular, access to basic services including health, education and transport have been highlighted as key issues in many remote areas across Europe. Over 50% of respondents to the public consultation on the long-term vision for rural areas stated that the most urgent need in rural areas is the creation of a better public transport system and access to basic services and amenities.[72]

Access to basic services in rural areas varies across member states, both in absolute terms and relative to cities. For instance, in EU rural areas, around 2.2 million people have unmet health needs at a rate per capita 25% higher than in cities.[73 74]

In addition, the quality of education tends to be lower in rural areas.[75] As a result, the levels of education are lower: only 28% of people aged 30-34 in rural areas have a university degree compared to 50% in cities.[76]

The benefits of connectivity to public services

This section discusses how digital connectivity can improve access to healthcare, education and wider government services in the EU's rural areas, and the wider benefits this can promote. For each of these benefit areas, a framework is presented to support policymakers in assessing the benefits of digital connectivity to these services.

Across these services, many Europeans desire greater digitalisation. For health services in particular, nearly half of respondents to a recent survey across Europe indicated that they would be interested in using e-health services.[77]

Health

Digital healthcare refers to tools and services that use digital technologies to improve prevention, diagnosis, treatment, monitoring and management of health-related issues.[78] Digital health can lead to improved healthcare in rural areas by removing the need to travel long distances to a medical facility and by providing access to more specialist care, which can reduce the greater unmet needs prevalent in some rural communities.

Telemedicine: Digitally enabled telemedicine allows patients and healthcare professionals, or groups of healthcare professionals, to connect remotely, improving access to and quality of care. A crucial aspect of telemedicine is the transmission of high definition medical images which enhanced connectivity will be essential in enabling. Even with 100Mbit speeds it would take three minutes to transmit a ten minute diagnostic video.[79] In the future, low latency connection could enable remote surgery and smart ambulances – potentially increasing access to specialised and emergency care for those in remote regions. Telemedicine will further allow patients to be monitored remotely post treatment, allowing for faster discharge, freeing-up hospital space and reducing re-hospitalization rates.

Ambient assisted living (AAL): AAL enabled by IoT can provide a positive influence on the health and wellbeing of people, especially the elderly, by supporting independent living. For instance, sensors at home can detect if accidents have occurred, and automated connected devices can automate jobs around the home. Smart fridges, for example, can order groceries when they run low.

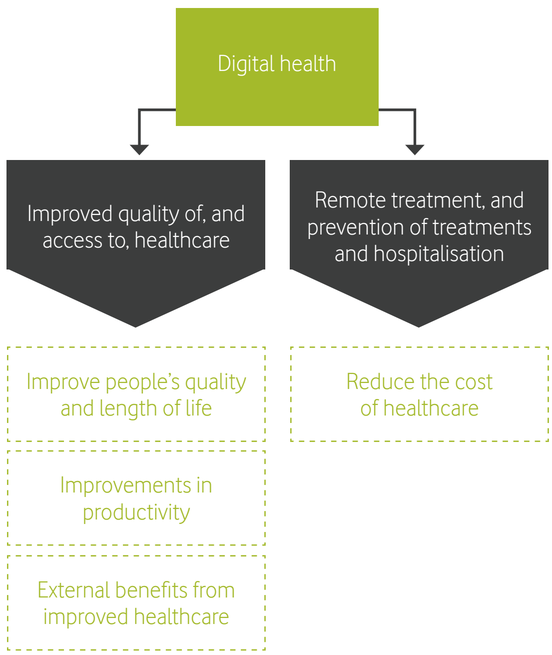
Preventative health: Wearable tech, such as smart watches, allow individuals to monitor their own health and provide data to healthcare professionals to identify health issues in a patient before they occur in order to provide preventative care.[80]

The transmission mechanisms by which digital connectivity can enable improvements to health and healthcare are shown in Figure 9.

Improved access to, and quality of, healthcare: The digitalisation of health services can provide a more efficient allocation of resources and improve the access to services by reaching patients in rural areas more easily. Telemedicine can further improve the quality of services by allowing medical personnel to focus more on care activities and improving the speed of diagnostic and treatments.[81] An EC report found that an increase in adoption of telemedicine of five percentage points could lead to a 1.7% increase in citizen's healthy life years and a 3.6% fall in mortality.[82] Digital healthcare can further lead to improvements in productivity, directly through less time spent receiving healthcare, and indirectly through later retirements and fewer sick days. Annual lost wages from absenteeism and early retirements have been estimated to be as much EUR 403 billion from chronic obstructive pulmonary disease (COPD) alone.[83]

Remote treatment and preventive care: Digital healthcare can reduce the transaction cost of providing healthcare services enabled by remote appointments and access to preventive care. For example, connected (IoT) wearables or implanted devices to support out-of-hospital care can reduce the costs of treatments by long-term monitoring of chronic conditions, enabling early detection of medical issues that can prevent or reduce severity of illnesses. The EU could save EUR 99 billion per year with 100% adoption of mhealth technologies.[84,85] The potential benefits of digital health solutions such as these are likely to increase as healthcare demand grows – public spending is expected to increase by 1.6% to 2.7% of GDP by 2020.[86]

Figure 9: Transmission mechanisms through which digital connectivity can improve health related outcomes



Source: Deloitte (2020)

Luscii app

Luscii was founded in 2018 and uses a mobile app to help prevent unnecessary hospital visits and admissions for vulnerable patients by increasing access to clinical support and improving the patient experience. Patients use the smartphone app to input their vital signs data. AI algorithms are then applied to the data to inform clinicians when patients' conditions are deteriorating and need attention. This has led to benefits across a range of conditions including a 65% reduction in hospital admissions for chronic heart failure, a 51% reduction in hospital costs for COPD and a 78% reduction in hospital admissions for gestational hypertension.

Source: Deloitte (2020)

Andalusia 5G Pilot

Drones, enabled by low latency 5G environments, have been trialled in providing emergency response services. Demonstration flights have shown that a drone equipped with a defibrillator can provide urgent healthcare four times faster than that of an ambulance, which has the potential to save many lives in time critical medical emergencies.

Source: Vodafone (2020)

The benefits to healthcare in rural areas of digital connectivity can be measured using the framework described in Figure 10. This analyses the effectiveness of digitally enabled healthcare solutions focusing on three key outcomes:

- **Health costs:** The difference in cost between traditional healthcare solutions and telemedicine, driven by reductions in transaction costs through remote appointments, and reductions in the quantity of non-remote healthcare.
- **Productivity:** Improvements in productivity for those receiving treatment through fewer sick days and less time spent on medical appointments, which traditionally occur during the workday.
- **Healthy life:** The change in the level of quality adjusted life years between traditional treatments and telemedicine.

An assessment of these benefits can be analysed for different health risks, either focussing more narrowly on particular conditions (for example, diseases which place a high burden on healthcare systems, such as circulatory disease or cancer) or covering a broader range of conditions.

The framework does not capture wider societal benefits such as increased resilience to pandemics, reduced care responsibilities of family members or reduced time and costs of transportation due to challenges in measuring these. For example, improved healthcare might be able to free up the time of individuals that would otherwise have to care for sick or vulnerable household members, potentially resulting in the take-up of additional work, and hence increased productivity.

Figure 10: Measurement framework for benefits from e-health[87]

	Market size of use case	Adoption rate	Impact	Monetization
Method	The market size can be determined by the population of interest for a specific use case. National statistic agencies are likely to be able to provide this data. For example: • Number of patients with medical conditions that could benefit from solutions such as e-health, wearables and assisted living based on data from the national health department. • Volume of consultations / treatments / hospitalisation needed for different illnesses. • Healthcare spending broken down by services and type of disease (costs of treatment / consultation)	The adoption rate reflects the willingness to take-up a specific use case and could be based on local surveys or use cases from urban areas, other countries or similar technologies. For example: • Ability and willingness of health care providers to adopt and offer e-health services. • Identifying the willingness of patients in rural areas to use e-health services (by age / health risk groups).	The impact can be quantified by conducting an analysis on benefits where networks have already been developed. Alternatively, surveys or use cases from urban areas or other countries could be used to inform assumptions. For example: • **Health costs:** Estimate the impact of a specific e-health service on measures such as reduced lengths of hospital stay, avoidance of treatment / consultation, etc. • **Productivity:** The impact on reduced number of sick days per year for illnesses attributable to a specific medical condition as well as the reduced number of lost years of working life. • **Healthy life:** Quantify changes in the level of quality adjusted life years (QALYs)	Financial values can be applied to outcomes that do not have a monetary value should robust shadow prices or methodologies be available. For example: • **Health costs:** Apply the cost per hospital stay, treatment, etc. to the reduced number. • **Productivity:** Use the average income in rural areas to value the increase in working time. • **Healthy life:** Apply a financial value to a one year increase in quality adjusted life years based on willingness-to-pay (WTP) studies. For example, the UK has estimated a value of £60,000.

Benefit specific considerations

Given the diverse characteristics of EU member states, governments will have to consider how the inputs for adoption rates and impact will vary based on country specific factors, for instance:

- **Digital skills:** The adoption rate of telemedicine is likely to be greater in countries where healthcare workers and citizens in rural communities have a high level of digital skills.
- **Health challenges:** The impact of e-health applications has the potential to be greater in countries where there are health challenges, such as staff shortages and where unmet health needs are high. In 2015, Poland had only 2.33 physicians per 1,000 inhabitants, and Romania 2.77, compared to 4.14 in Germany and 5.1 in Austria.
- **Demographics:** The benefits of digital health have the potential to be greater for citizens in countries where depopulation has led to an ageing society with greater incidence of chronic conditions that require regular consultation. For instance, over a quarter of citizens in rural Spain and France are over 65, compared to only 16% in Ireland. While older age groups would be most likely to benefit from e-health, they are also the group least likely to adopt new technology.

Examples

- The Digitising Europe Pulse survey by the Vodafone Institute for Society and Communications found that 25% of respondents in Europe use e-health services and a further 45% would like to use this in the future.
- The UK Department of Health's Whole System Demonstrator programme was launched in 2008 and investigated the impact of telemedicine and remote care, involving 6191 patients. The programme found that telehealth can deliver a 15% reduction in accident and emergency (A&E) visits, a 14% reduction in hospital bed days, and a 45% reduction in mortality rates.
- Studies accessing the improvements in QALYs and the cost of different e-health interventions

Outcomes should be presented in Net Present Values (NPV) using an appropriate discount rate.

Education

The availability of enhanced digital connectivity in a community can enable greater access to, and quality of, education services, increasing overall levels of education, as well as embedding digital skills learning in education. These transmission mechanisms, by which digital connectivity can enable educational improvements in rural communities, are shown in Figure 11.

Increased levels of education: Digital connectivity to rural communities, leading to the greater use of digital tools, can enable remote learning as classes can be live streamed and can improve access to educational content outside of school. In the classroom, enhanced connectivity can allow access to innovative educational tools such as remote field trips and specialist teaching resources which can improve the quality of education and enhance pupil engagement. These benefits could be greatest in rural communities, as remote learning can mitigate the challenge from the time and cost expense of travelling further to school, increasing student participation. Furthermore, teleconferencing can allow for small rural schools to coordinate classes together, reducing the problems of high staff turnover.

Improved digital connectivity can also allow for remote and blended learning[88] for higher education and training. Digital tools can open up classrooms to wider audiences and help meet the rising demand for tertiary and life-long education. Improved access to digital education resources can help education in remote communities to become more cost effective and engaging. A recent survey of European citizens found that digital education tools are already used by 36% of respondents and a further 28% would like to use these in the future.[89]

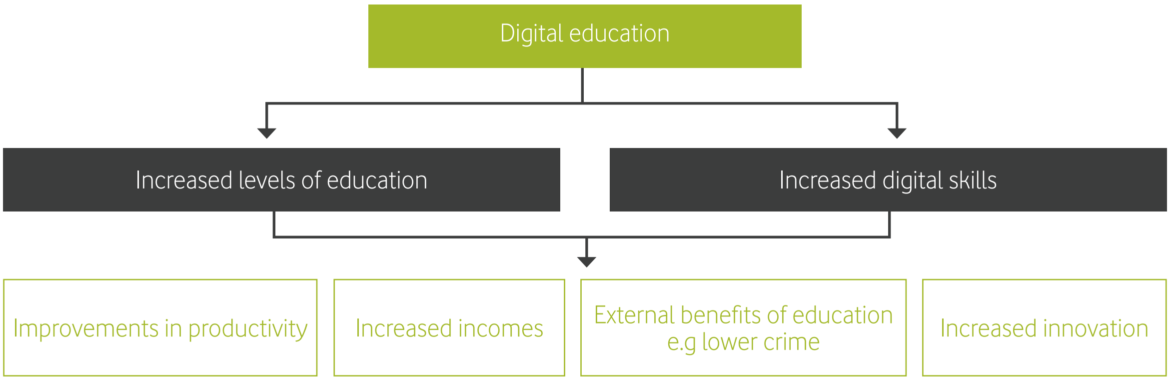
Fibre can be instrumental in promoting the use of digital tools in education through providing symmetrical upload and download speeds. This can be important in allowing for the fast upload of educational content where, using fibre, a traditional educational video can be uploaded in less than a minute.[90] Evidence from New Zealand suggests the rollout of fibre to schools led to a one percentage point increase in primary school pass rates.[91]

However, teachers will need to be provided with training and support in order to adopt digital technologies. In 2018, less than 40% of educators in the EU felt ready to use digital technologies.[92] In addition, without access to connectivity in rural communities, increasingly online courses may exacerbate the educational divide that exists between rural and urban communities.

Better quality and longer education can lead to increased levels of productivity and incomes for those in rural communities, greatly reducing the chances of being in poverty.[93,94] Higher levels of education can promote knowledge and spillover effects by sharing information with others, which can increase productivity across the EU. Education also has several non-economic benefits to individuals and society such as improved levels of health, higher levels of children's education and increased levels of social capital which can lead to less crime and more societal involvement.[95]

Increased digital skills: Improved education through digital connectivity can also improve digital skills, which can have further advantages at both a macro and micro level. At a macro level, digital skills are becoming increasingly important for businesses, accessing high income jobs, and engaging in society. 85% of jobs in the EU required at least basic digital skills.[96] However according to DESI more than 40% of Europeans still lack these skills,[97] and over 70% of businesses in the EU reported that the lack of staff with adequate digital skills is an obstacle to investment.[98] At a micro level, the importance of digital skills is reflected in an ICT wage premium,[99] suggesting that increased digital skills could help promote incomes among rural communities.

Figure 11: Transmission mechanisms through which digital connectivity can promote educational benefits



Source: OECD (2019)

Case study example: Picoole Scuole (Small Schools)

Piccole Scuole is a project in Italy that seeks to promote distance learning in geographically isolated small schools through shared teaching and expanded learning environments.

Through shared teaching, two or more classes belonging to different schools are connected to each other through the daily use of videoconferencing. This fosters an exchange of experiences and ensures the teaching of all subjects for children in multi-age classrooms.

An expanded learning environment can complement traditional teaching. One or more classes can work on a common project and organise periodic meetings between teachers, students and/or experts who can use videoconferencing as well as other digital tools according to the type of project.

Source: OECD (2019)

The framework below measures the benefit of increases in education and digital skills to incomes. This excludes several further benefits, where quantification would be challenging including:

- Benefits to businesses such as improved worker education and productivity, above what they share through higher incomes.
- The benefit of improved digital literacy in the uptake of other digital services and tools or the impact of knowledge spillovers on the economy.
- The indirect benefits of increased levels of education such as reduced crime, which tend to be lower in rural areas compared to cities. Several studies suggest these "non-market" effects are of a similar order to the earnings impact of improved education.[100]

Figure 12: Measurement framework for benefits from digital education

	Market size of use case	Adoption rate	Impact	Monetization
Method	The market size can be determined by the population of interest for a specific use case. National statistic agencies are likely to be able to provide this data. For example: • Number of schools within the rural region that could be connected. • Number of students that could benefit from technologies such as distance learning. • Number of adults in the region that could benefit from virtual vocational training and enhanced access to information. • Number of businesses with a low level of digital skills and number of vacancies that require digital skills.	The adoption rate reflects the willingness to take-up a specific use case and could be based on local surveys or use cases from urban areas, other countries or similar technologies. For example: • Estimating the potential take-up of technologies such as e-learning or digital tools. • Willingness and affordability to connect schools and deploy digital equipment. • Availability of sufficient online services and engagement with online services.	The impact can be quantified by conducting an analysis on benefits where networks have already been developed. Alternatively, surveys or use cases from urban areas or other countries could be used to inform assumptions. For example: • **Improved education:** Digital education can improve the quality of education, and increase the exam pass-rate and the number of years of schooling. • **Increased digital skills:** Estimate the impact of e-learning technologies on the digital skill level (e.g. DESI index). • **Employment:** The impact of increased digital skills on finding employment.	Financial values can be applied to outcomes that do not have a monetary value should robust shadow prices or methodologies be available. For example: • **Improved education:** Apply additional discounted lifetime earnings to the increase in education (country level data on the average earnings by educational attainment level). • Alternatively estimates of schooling on labour productivity could be used to proxy for the increase in incomes • **Increased digital skills:** An ICT wage premium can be applied to the increase in digital skills.

Benefit specific considerations

Given the diverse characteristics of EU member states, governments will have to consider how the inputs for adoption rates and impact will vary based on country specific factors, for instance:

- **Cost of education:** Other barriers to traditional education such as high costs of educational / vocational programs which vary between EU countries may influence the take-up of distance learning. The adoption rate is likely to be higher in countries where education is free of charge such as in Sweden or Denmark.
- **Job opportunities:** The demand for occupations with higher-digital skills in the EU is concentrated in urban areas, therefore it is likely that complementary policies are needed that enable teleworking opportunities in order to realise benefits of increased digital skills within the rural communities.
- **Remoteness of rural communities:** More remote communities will face greater barriers to higher quality education, and so stand to gain more from digital education.
- **Distributional weighting:** A higher social value can be given to an increase in earnings of lower income households based on the principle of diminishing marginal utility of income.

Examples

- The Digitising Europe Pulse survey by the Vodafone Institute for Society and Communications found that digital education tools were already used by 36% of respondents in Europe and a further 28% would like to use these in the future.
- The Centre for the Economics of Education (2007) has estimated that individuals who have learnt basic digital skills could expect a lifetime increase in average hourly earnings of at least 2.8%
- The UK Greenbook provides an estimate of the marginal utility of income at 1.3 for distributional weightings based on established literature.

Values of additional lifetime earnings should be presented in Net Present Values (NPV) using an appropriate discount rate.

Government services

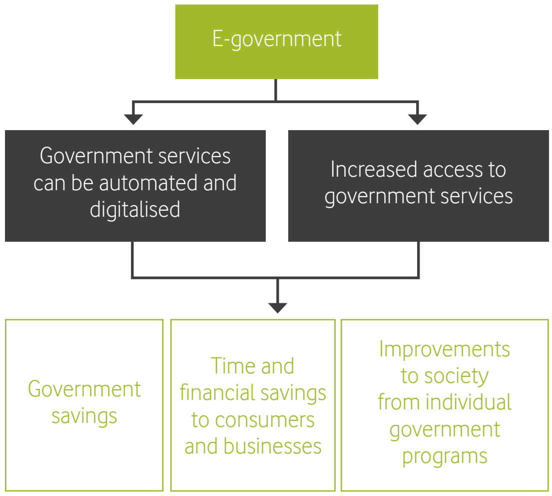
Digital connectivity in communities can support the transition to e-government services. E-government is a term used to denote any government systems, processes, or functions that rely on digital technology, and that are executed over the internet. This can range from accessing information, participating in democracy and completing financial transactions such as paying taxes.

Digitalisation of government services: For citizens and businesses in rural communities, e-government services can reduce frictions while interacting and transacting with government. This can reduce the time it takes for citizens and businesses to interact with government. For instance, the EU's Once-Only project to reduce administrative burdens and facilitate cross-border business, is expected to save citizens and businesses 855,000 hours and EUR 11 billion respectively each year.[101]

E-government can further lead to government savings from improvements in efficiency from reducing the cost of transactions, and reductions in error rates.[102] The savings from providing e-services are potentially large. In Denmark, electronic invoicing saves taxpayers EUR 150 million a year and businesses EUR 50 million a year. If introduced across the EU, annual savings could exceed EUR 50 billion.[103]

Increased access to government services: The provision of e-government services in rural areas could further mitigate barriers to access such as long travel distances, which can be particularly beneficial for older people who may not be able to drive on their own anymore.[104] Digital connectivity in all rural communities would enable equal access to government services, mitigating the risk of digital exclusion and allowing for increased participation in society.

Figure 13: Transmission mechanisms through which digital connectivity can promote e-government service benefits



E-government services in Estonia

Estonia has been at the forefront of providing services for its citizens online. The e-Estonia policy, which has been running for over 20 years, enables the country to offer several e-services including, e-taxes, e-health, e-police, e-school or i-voting. For example, 99% of public services are available online 24/7.

Estonia has estimated that at least 2% of GDP is saved due to the usage of digital signatures, and that 800 years of working time are saved due to data exchange every year. Additionally, around 44% of Estonia's citizens use i-voting. The processing of a regular vote costs around EUR 20 while the cost of processing an e-vote is only around EUR 2.

Estonia has taken the next step in digitalisation by implementing its Government Cloud solution to modernise its existing information systems. The cloud platform enables Estonia to deliver, manage and audit government services in a secure way.

Source: e-Estonia (2020); European Commission (2018)

The framework for measuring benefits of digital connectivity in rural areas to public services is outlined in Figure 14. This covers potential savings to government from e-services and potential time and cost savings to workers and businesses from quicker access to government. In addition, quality of service benefits may be estimated by understanding willingness to pay for improved quality of public services. However, other benefits of wider take up of government services, such as improved social capital from voter participation are more challenging to quantify.

Figure 14: Measurement framework for benefits from e-government services

	Market size of use case	Adoption rate	Impact	Monetization
Method	The market size can be determined by the population of interest for a specific use case. Data from National Statistics Agencies or the Department for Finance could be used. For example: • Volumes on the number of different transactions, corresponding to the channel and transaction type information. • Number of people engaging and using government services broken down by type of service	The adoption rate reflects the willingness to take-up a specific use case and could be based on local surveys or use cases from urban areas, other countries or similar technologies. For example: • Willingness amongst those in rural areas to take-up e-government services (by demographic characteristics).	The impact of a specific technology can be quantified by conducting an analysis. Alternatively, expert surveys or use cases from urban areas or other countries could be used to inform an assumption. For example: • **Government cost saving:** Difference between the costs of providing e-government services and traditional services • **Time savings:** Quantify the impact on reduced time spent per person / business on online services compared to traditional ones. • **Quality of service:** Estimate improved service quality based on customer satisfaction surveys.	Financial values can be estimated for non-monetary outcomes by using shadow prices where available. For example: • **Government cost savings:** no conversion needed as outcomes are already stated as financial values. • **Time savings:** The value of time saved for an additional hour of work can be monetized based on the average income per hour in rural areas (by industry). The value of an extra hour of leisure time can be estimated based on willingness-to-pay (WTP) studies. • **Quality of service:** The value of increased quality could be measured based on WTP studies.
Benefit specific considerations	Given the diverse characteristics of EU member states, governments will have to consider how the inputs for adoption rates and impact will vary based on country specific factors, for instance: • **Digital literacy rate:** The adoption rate of e-services is likely to depend on the digital literacy rate of a country and the level of digital skills within public sector organisations. In addition, the public perception of providing those services online will likely impact the service take-up. For countries such as Bulgaria or Romania, where only 26-28% of the population has basic digital skills it might be more difficult to provide e-government services. • **Status quo:** Countries that have a relatively high population share with basic digital skills but are still providing most of government services in a traditional way, are likely to have the greatest potential to benefits from the provision of e-services.			
Examples	• Denmark has digitalised 80% of its services in 2015. Digital post which enables citizens to receive digital letters, notices and messages from the government is estimated to save the public sector 1bn DKK (around €134m) each year. • Additionally, the electronic invoicing saves taxpayers c. €150m and businesses €50m a year. • It is estimated that the introduction of eGovernment could lead to annual savings of over €50bn if introduced across Europe. • In Italy, the adoption of e-procurement systems was able to cut government costs by over €3bn. • The provision of Government Digital Services (GDS) such as vote registrations or tax payments has led to cost-savings of £600m in 2015 for the UK government. • The UK Department for Transport has established values for time savings, the average value for an additional working hour is valued at c. £19, and the value for an additional hour of non-working is valued at £5-10.			

Outcomes should be presented in Net Present Values (NPV) using an appropriate discount rate.

Social Inclusion

Social inclusion in rural areas

Social inclusion is a process which ensures that those at risk of poverty and social exclusion gain the opportunities and resources necessary to participate fully in economic, social and cultural life and to enjoy a standard of living and wellbeing that is considered normal in the society in which they live.[105]

Rural communities are often disadvantaged due to an ageing population, a weaker labour market, limited access to education and basic services, and increased travelling costs.[106] For this reason, social, territorial and economic cohesion is one of the key priorities of the EU, aiming to reduce disparities between the level of development of regions, with a particular focus on rural areas.

The EU invested EUR 33 billion in social cohesion investments between 2014 and 2020 to support rural-urban linkages and community-led rural development programmes.[107] For example, a project in the Castellon Province in Spain launched a rural taxi service which provides free transport for residents who do not have their own transport to hospitals, medical and dental centres.[108]

Despite initiatives to address social inclusion in rural areas, 41% of people living in rural areas have indicated that they still feel left behind by society and over 70% do not feel that public policy is designed with special attention to rural areas.[109] The development of rural areas will continue to play an essential role in promoting a more inclusive society by creating new opportunities and supporting vulnerable groups such as the elderly, women and people with disabilities.

The benefits of connectivity to social inclusion and wellbeing

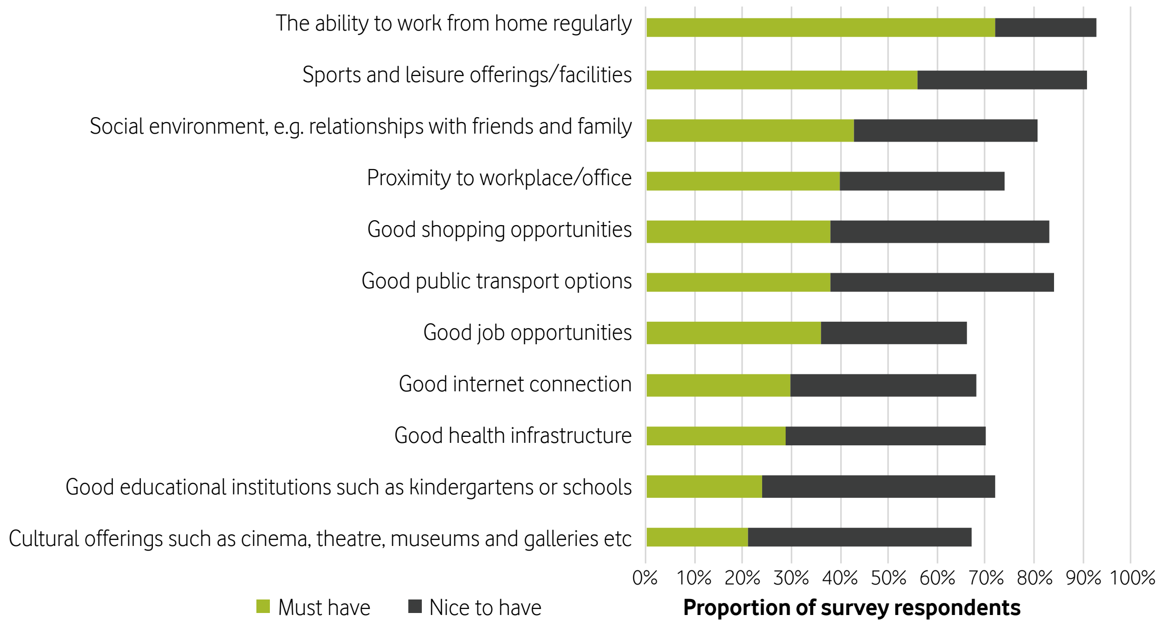
Enhanced digital connectivity can have a direct impact on social inclusion through improved communication tools. For example, digital services promote community resilience[110] by making it easier for remote or disparate communities to organise online. Connectivity can also help reduce isolation among more vulnerable and remote citizens by enabling social interactions online.

Digital connectivity can promote access to new digital services, such as e-commerce and culture, among rural communities. The ability to shop online provides rural consumers with access to lower prices and more choice. Similarly, it can also allow citizens to stream and upload media content and access news, literature and virtual museums.[111]

In addition, connectivity-enabled benefits in the other areas of the long-term vision, such as higher quality and reliable jobs, sustainable development and access to education and health services, indirectly contribute to social inclusion and increase levels of wellbeing amongst those in rural areas. Therefore, connectivity supporting greater digital inclusion can have an important role in improving the quality of life for those in rural communities.

Reducing the quality of life divide between rural and urban areas and improving national cohesion also encourages greater migration of urban citizens to rural communities. More people are then able to enjoy the benefits of rural life whilst reducing pressures on housing and transport in urban locations. A recent survey of European citizens found that 56% of Europeans living in urban areas across could imagine moving to the countryside in the next two years, with closeness to nature and a healthier environment highlighted by urbanites as the key advantages of country life. However, urbanites also highlighted several requirements to support migration to rural areas shown in Figure 15. Of most importance was a good internet connection, which was seen as more important than health infrastructure, public transport and job opportunities.

Figure 15: Conditions that urbanites would require to move to the countryside



Source: Vodafone Institute for Society and Communications (2021), Digitising Europe Pulse #5: Focus on the rural-urban digital divide

Smart villages:

Across Europe, member states are investing in the creation of Smart Villages, which use digital tools and e-services to improve their resilience, building on local opportunities. This is supported by the European Parliament which has allocated EUR 3.3 million to support the development of ten smart villages across the EU.

For example, the Fraunhofer Institute has created the "Digital Villages" project in Germany in 2015 with the objective to develop a digital ecosystem for rural areas. The Institute has worked closely with local communities to consider specific aspects of the creation of a digital platform that ensures the needs of the communities are met. This has enabled these villages to benefit from digital solutions in improving the supply of local goods, communication, mobility and e-government.

Vodafone Portugal's Fountain partnered with the Seia Municipal Council to enable high-speed connectivity to the village of Sabugueiro, transforming it into Portugal's first smart mountain village. The digital transformation has enabled the usage of IoT technology, which helped to cut resident's energy consumption by c. 20% and reduce maintenance visits to water stations by 50%. The installation of smart LED lights helped further reduce consumption by 880 kWh per year, reducing bills by 75%.

In addition, high-speed connectivity has enabled increased access to services such as health. For instance, c.60% of residents stated that their health has improved through telemonitoring programmes and c.70% mentioned that e-health services helped them to better understand treatments, allowing for a greater control over their health.

Source: European Parliament (2021); European Network for Rural Development (2018); Vodafone (2020)

Social inclusion and wellbeing can be measured by using quality of life surveys that measure life satisfaction based on a wide range of indicators. For example, the European Quality of Life Survey examines factors such as income, education, housing, family, work-life balance, health, level of happiness and how people perceive the quality of their society.[112] Surveys conducted at regional level can be used to assess the potential benefits of enhanced connectivity to social inclusion and wellbeing in rural communities.

Based on survey results, econometric analysis can provide a method to estimate the impact of high-speed connectivity on quality of life. Some of the indirect benefits on wellbeing, such as better income and health, can be controlled for in this analysis, mitigating the risk of double counting benefits described in the other areas.

Finally, a monetary value can be applied to any measured increase in quality of life based on the additional income needed to support the same welfare improvement. For instance, the UK evaluation of the impact of superfast broadband has valued the associated increased in wellbeing at c.£225 per premises upgrade per year.[113]

The extent of wellbeing benefits likely depends on the digital literacy rate and living standards within a country and can vary by demographic characteristics, such as age. For example, the proportion of adults with basic digital skills in the EU is 56%, however this varies from 79% in Denmark to 29% in Bulgaria.[114] Improvements in the quality of life could therefore be greater amongst groups who use the internet more frequently.

The challenging economics of rural networks

The economics of rural networks are challenging. As a result, costs are relatively higher on a per subscriber basis than in urban areas. Furthermore, the amount of direct revenue generated by rural network investments is often insufficient to cover the cost of that investment and therefore insufficient to provide a commercial incentive for investors. There are supply-side and demand-side factors driving this, which compound to create the challenging economics that have tended to result in rural areas being under-served by telecoms networks.

On the supply-side, the cost of deploying and maintaining networks across often widely dispersed populations, coupled with specific rural deployment challenges and the reduced economies of scale arising from servicing smaller populations, makes the cost of serving each individual rural subscriber higher than is the case for urban subscribers.

On the demand-side, the relatively lower number of subscribers served by rural networks, combined with often lower income levels amongst rural populations, reduces the amount of revenue that can be generated by rural networks compared to urban networks. Increased network deployment in those areas could help to boost the local economy, driving increased income levels and thereby generating a greater revenue opportunity of rural networks. However, this is uncertain and therefore difficult to capture in investment cases.

The aggregate effect of relatively higher costs per subscriber and relatively lower subscriber revenues makes the commercial case for rural networks more challenging. Absent license obligations and other policy incentives, the rational commercial investor would likely elect not to deploy networks widely in rural networks. As a result, the positive economic and social externalities outlined earlier in this report would be lost.

These challenges are multiplied when considering enhanced connectivity technologies such as 5G and fixed gigabit networks, due to the increased level of equipment needed to support the higher speeds and lower latency offered by these technologies.

This section of the report examines the main drivers of the challenging economics of rural networks, highlighting key issues encountered when deploying and maintaining these networks, and identifying practical examples of how these play out in practice. An understanding of these drivers provides useful context for any evaluation of the costs and benefits of rural networks, as well as for an assessment of the policy options that could help address the issues.

Economics of telecoms networks

The fixed costs of deploying telecoms networks, whether fixed-line or mobile cellular, are considerable. Before a single call minute or megabyte of data can be transferred, an entire network infrastructure needs to be deployed. Whilst some costs increase with the quantum of call and data traffic, a significant proportion of network costs are fixed in respect of the volume of network traffic generated by customers.

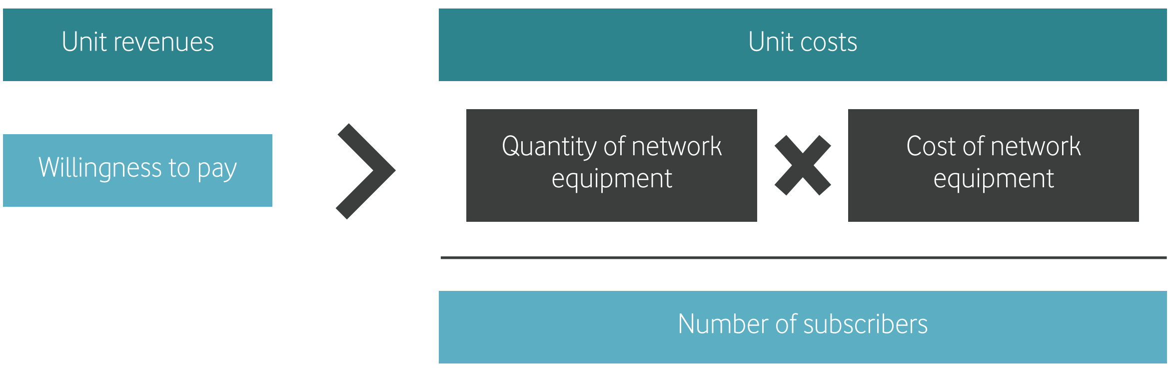
Similarly, a single cell in an urban area may provide coverage for over 1000 subscribers, whilst a rural cell may provide coverage for less than 50.

These fundamental characteristics of telecoms network deployment mean that economies of scale play an important part in the commercial investment equation. In simple terms, the greater the number of customers that can be served, the lower the unit cost of provision will be; further, the more customers that are served, the more revenue will be generated. In urban areas it is possible to serve a relatively high number of customers, who share the use of mobile cells and fibre cables in a way that significantly reduces the average cost to serve per subscriber.

However, as illustrated in Figure 16 below, it is not just the amount of network equipment deployed per subscriber that drives the relatively higher unit cost of rural network deployment. There are also specific characteristics of rural networks that make installation and maintenance costs higher than in urban contexts.

When combined with the economies of scale effects described above, the gap between the cost to serve rural areas and the revenue generated by subscribers in those areas is clear.

Figure 16: Simplified example of the network rollout decision

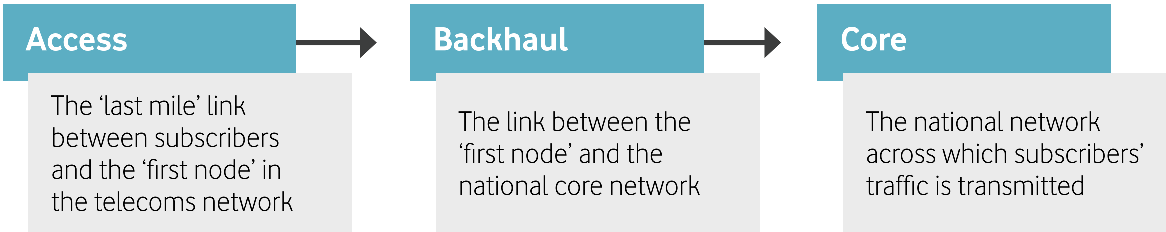


The remainder of this section of the report provides a high level overview of the structure of fixed and mobile telecoms networks, how the associated costs are affected by the limited economies of scale and specific deployment issues encountered in rural areas, and how demographic considerations impact the commercial returns that can be generated by network deployments in these areas.

Telecoms network costs

In simple terms, national public telecoms networks, both fixed and mobile, are made up of three primary elements.

Figure 17: The 3 elements of national public telecom networks



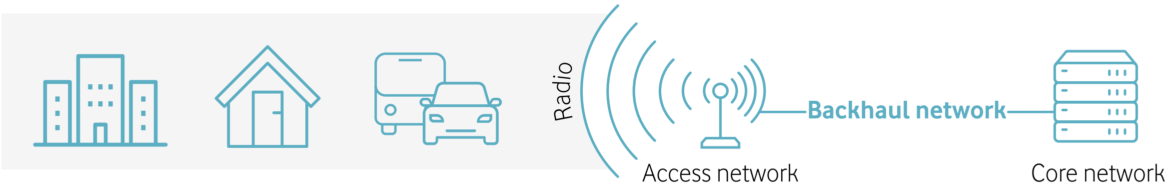
The primary difference between the economics of fixed and mobile deployments is in the access network; however, both network types provide connectivity to subscribers using equipment whose cost varies according to the number of subscribers connected, as well as the distance between them and the first node. As such, whilst the specifics are different the underlying drivers of the cost of deploying fixed and mobile networks in rural areas are similar.

High level overview of mobile networks

Mobile radio networks consist of three elements:

- **The radio access network, or RAN:** encompassing cellular base station equipment and the sites at which they are deployed, which together provide the radio coverage and capacity on which subscribers' mobile connectivity is based.
- **Backhaul network:** providing connectivity and capacity between each RAN base station and the core network, using either fibre or microwave transmission technologies.
- **The core network:** providing the nationwide transmission nodes and intelligent platforms, and the connectivity and capacity between them, enabling calls and data to be exchanged between subscribers nationally.

Figure 18: Basic topology of a mobile network



Extending network coverage in rural areas primarily requires investment in the RAN and backhaul networks.

RANs require extension through the deployment of additional cell sites, and/or the upgrade of existing cell sites. The number of sites that an operator needs to deploy in a given area will depend on several factors including:

- the level of **coverage** required (i.e. the geographic area over which the operator is seeking to provide mobile services), with more sites generally required to provide wider coverage (all else being equal);
- the **capacity** that the cells are required to deliver, given the level of demand in a given area which is determined by factors such as population density and mobile use cases (i.e. the bandwidth available to be shared between subscribers in each cell) – in general a higher density of sites can help increase network capacity; and
- the **spectrum frequency** used, with low frequency spectrum enabling a single cell site to provide mobile coverage for larger areas than higher frequency spectrum, due to differences in propagation characteristics, thereby reducing the number of sites required to provide a given level of coverage.

Each of these factors needs to be taken into account by operators to provide reliable high-quality mobile services. Decisions as to site deployment are in turn then affected by other factors such as the topography of the terrain, site availability and the extent to which in-building coverage needs to be provided.[115]

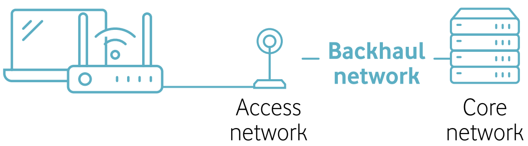
Backhaul networks need to be expanded as the RAN extends, increasing the number and/or capacity of links. Core networks are less likely to require direct additional investment to accommodate expansions in rural coverage and capacity.

RAN expansion costs will include capitalised expenditure associated with site construction and equipment deployment; ongoing operating costs relating to, for example, maintenance, power, site rental charges and access permissions can be expected to rise in proportion to the number of additional sites. Similarly, backhaul network expansion costs will include either capitalised expenditure relating to the deployment of new fibre or microwave radio links, and/or operating expenditure relating from the rental of dark fibre or leased line connectivity.

High level overview of fixed networks

As is the case with mobile networks, fixed-line networks are comprised of access, backhaul and core elements. The key difference is in the access element; voice and data traffic is transmitted between subscribers and the first network node using either copper or, more usually in contemporary deployments, fibre cables as opposed to cellular radio.

Figure 19: Basic topology of a fixed network



Each subscriber premises has dedicated connectivity, with scope for the sharing of cabling as paths aggregate towards the first network node. There are very substantial fixed costs in delivering this dedicated connectivity although the scope for sharing and aggregation enables economies of scale to be realised where population densities allow. The deployment of new infrastructure in areas with highly dispersed premises reduces the scope for economies of scale to be realised, and – as with mobile networks – there are specific characteristics of rural areas that can increase the connectivity costs compared to urban areas.

As a result of these factors, a recent study found that the cost of expanding European FTTP networks to enable 100% of premises to be 'passed' and 50% 'connected' could be as high as EUR 156 billion in the absence of any cost reduction measures.[116] However, the costs of providing fibre connectivity to households and businesses can vary significantly both between and within EU member states with costs increasing very significantly in rural communities. In this context, the Irish government is spending EUR 2.9 billion[117] to support the delivery of high-speed broadband services to 540,000 previously under-served rural premises.[118]

Expanding rural networks

The following sections examine why access and backhaul network deployment costs associated with extending fixed and mobile network coverage in rural areas are relatively higher than in urban areas, and provide some specific examples from various EU member states.

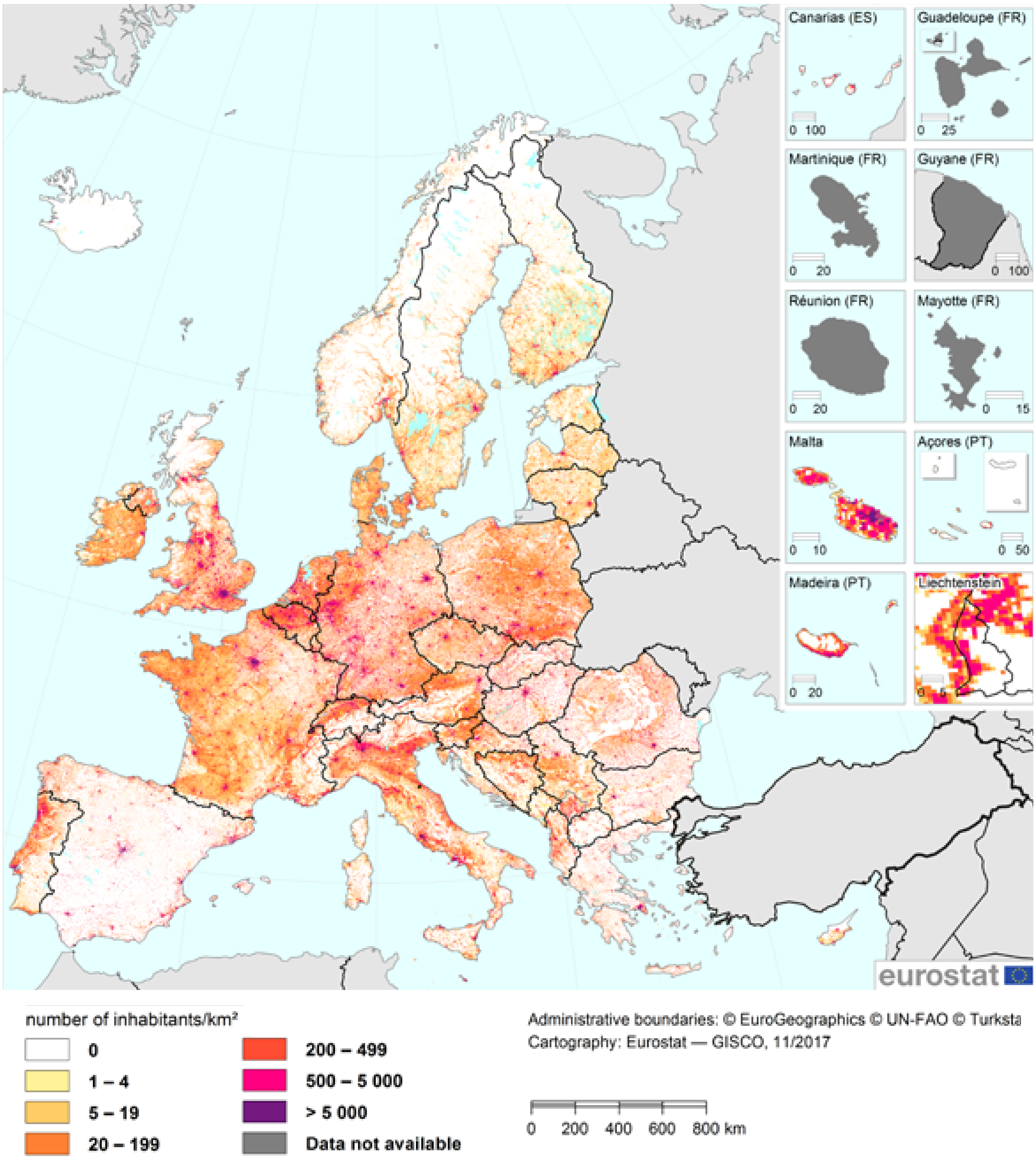
First, the characteristics of rural areas that result in the need for a greater quantity of equipment per subscriber are considered. This is followed by a review of the characteristics of rural deployments that increase the cost of deploying and maintaining network equipment. Finally, an assessment of the implications for the cost of backhaul networks is provided.

Rural network expansion costs - drivers of relatively more network equipment per subscriber

Population density

Across Europe, population density is much lower in rural communities, which in many areas consist of only a small number of dwellings per km^2; indeed, as highlighted in Figure 20 below, 40% of the EU populated landmass has a density of less than 20 per km^2.[119]

Figure 20: Population density of the EU and UK per km², based on 2011 census



Source: GEOSTAT Population Grid 2011[120]

For mobile networks, the lower population density in rural areas mean that, for a given level of spectrum propagation, fewer subscribers can be covered by each cell. As a result, the number of sites required to cover a given number of subscribers can be much higher compared to in urban areas.

Case Study: Ireland has a low average population density of 69/km^2 relative to 117.5 per km^2 in the rest of the EU. However, the Irish population distribution is skewed across the country; the urban population accounts for 63% of the population and is concentrated in just over 2% of the land mass.

Conversely the remaining 37% of the population inhabits the remaining 98% of the land mass, and at the most extreme, the last 3% of the population inhabits 28% of Ireland.[121] The dispersed nature of these remote communities therefore requires a relatively greater number of cell sites than more densely populated areas to cover an equivalent proportion of the population.

Estimates suggest that to increase population coverage of 3Mbps by 2.8%, from 96.7% to 99.5% would require an 18% increase in the number of sites.[122]

Source: ComReg, Meeting Consumers' Connectivity Needs

As Figure 20 above shows, population density, and therefore the number of subscribers per sites, varies both across and within EU member states. Countries with more sparse populations and large numbers of small communities, as in Ireland, will face greater challenges in rolling out rural networks.

In urban areas, the number of sites needed is generally determined by capacity constraints, reflecting the relatively high number of subscribers making use of the network at the same time. By contrast, in rural communities, the relatively lower number of subscribers, and Consequently the lower capacity demand, tends to mean that cell radii are constrained primarily by potential propagation distances.

Propagation limits are a particular issue in respect of 5G networks that provide high bandwidth connectivity to subscribers. 5G networks will be provided over a range of spectrum, including 700 MHz (low band), 1.5-6GHz (mid band) and above 6GHz (upper band).

While low band frequency will allow for high levels of coverage, it will not provide gigabit-capable speeds. Mid-band spectrum will be needed to allow for higher capacity use cases. However, higher frequency spectrum has weaker propagation characteristics, so more sites will be required.

The key driver of costs incurred when extending mobile coverage in rural areas is the number of new sites that will be required to reach the marginal one percent. This is illustrated by Figure 21 below, which shows the considerable increase in the number of sites needed to extend population coverage above 95% in Romania. However, this will also vary by country; in Romania, to increase population coverage from 95% to 99% it is estimated to require 1,500 additional cell sites, covering on average 500 people per site. In comparison, it is estimated that 350 sites would be needed to increase population coverage from 95% to 99% in Greece, at an average of 1,100 people per site.

Figure 21: Estimated additional sites needed to increase coverage from 65% in Romania

Population Coverage

75%	85%	95%	99%
375 sites	870 sites	1400 sites	2900 sites

Source: Based on Vodafone Opco market data

For fixed networks, lower population densities and greater distances between premises can also increase the unit cost of networks and can reduce the economies of scale from sharing network equipment. For instance, the costs of developing civil infrastructure such as ducts, which can account for up to 80% of the costs to roll out an FTTP network,[123] can be shared between many premises in urban areas. In contrast, the cost of the ducts and poles providing connectivity to rural communities must be shared among considerably fewer premises.

Not only will costs be shared between fewer households, lower population densities also tend to increase the distance between aggregation nodes and subscriber premises. This can increase the network cost as greater distances require more ducts, poles and fibre to be installed and for wayleaves to be agreed. Greater distances also increase the number of wayleaves that need to be signed and funded, which can increase the cost and slow down the development of rural networks.

Impact of rural topography

Beyond the dispersed nature of population, rural areas also present specific topographical challenges that impact the cost of network deployment.

For mobile networks, hills and woodlands can block or weaken signals resulting in each cell covering a smaller area and some premises receiving poor or no coverage. Mountainous areas in particular require more sites to cover every premises as additional sites may be needed to provide service to valleys containing a small number of subscribers. In this context, it should be noted that approximately 20% of EU citizens currently live in mountainous municipalities, increasing to as high as 50% in Austria and Greece.[124]

The increased distance between the cell site and subscribers in rural communities can also have implications for the quality of a mobile service, as potential speeds available fall with distance from the cell site. This could limit the available use cases of 5G technologies that require high speeds and low latency; or require the densification of rural networks, exacerbating the issues of number of sites per subscriber.

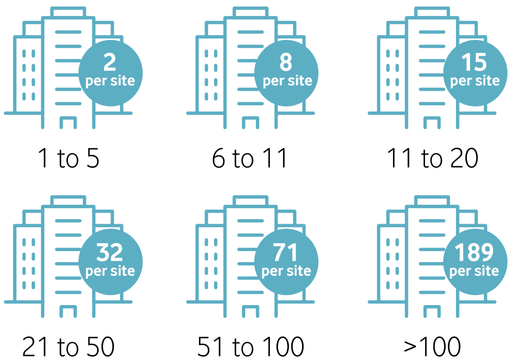
For fixed networks, mountainous terrain may mean that less direct routes are needed to reach specific outlying premises, thus increasing the network route distances involved. Mountainous areas may also contain rockier terrain, which makes it harder to build ducts underground and support poles, thus increasing cost. As mentioned above, several EU member states have large numbers living in mountainous regions, which increases the cost of rural fixed networks.

White spots

Mobile network operators are not always able to locate their sites in the ideal locations to maximise coverage, for example due to planning restrictions, which can be particularly restrictive in rural areas. This can result in a small number of premises in an otherwise covered village being unserved or receiving lower network speeds. Tower heights can also be constrained by planning rules, which can reduce the total area a site can cover, thus increasing the total number of sites that need to be developed.

Figure 22 highlights how increasing coverage to 100% in Spain, would require the development of sites that provide service to very small numbers of individual subscribers. In municipalities with very high coverage levels, expanding coverage to any final unserved subscribers would mean deploying sites that cover a very small number of subscribers per cell site.[125]

Figure 22: Number of people covered per site based on the remaining population to be covered in a municipality



Source: Based on Vodafone Opco market data

As shown here, there are multiple factors that drive the increased cost of network equipment deployed per subscriber and premises in rural areas, relative to urban areas. However, the impact of these factors will vary according to the unique characteristics of each rural area.

Rural RAN expansion - drivers of relatively higher costs of rural networks

The above section highlighted how network expansion in rural areas can be more costly due to the greater quantity of access network equipment, such as sites, ducts, poles and fibre, required per subscriber or premises served. However, in rural areas the cost of deploying and maintaining network equipment can also be relatively higher than in urban areas. This section discusses some of the key issues increasing these costs in rural networks.

Availability of supporting non-telecom infrastructure

Optimal site locations for coverage in rural areas may not have the necessary supporting non-telecom infrastructure nearby. Access roads and electricity connections are both examples of supporting infrastructure which, if not available within range of the optimal site for network equipment, can compromise the location of the equipment and/or increase the cost of developing and maintaining the network. This particularly affects mobile networks costs. For example, access and power-related costs in Romania, whilst varying by site, could be as high as 70% of the total cost of a new site,[126] thus requiring significantly more investment and compounding the challenging economics of achieving coverage in the most isolated rural areas.

Mobile sites require a reliable connection to power the active base station equipment. In urban and suburban areas there is likely to be a reliable power connection nearby or already available, thus reducing the cost to connect to the electricity grid. However, in rural areas, particularly where a site is being located on land some distance from the nearest premises or road, there is unlikely to be a power connection nearby. In these instances, the network operator will usually contribute to the cost incurred by the local electricity network provider to connect the site to the electricity grid.

Case Study: Romania

In in some rural locations in Romania, the upfront cost of connecting to the electricity grid is five times higher than average site power costs.

Source: Based on Vodafone Opco market data

In some circumstances, such as in mountainous areas, network operators find that connections to the grid are sufficiently expensive that 24-hour generators must be used, costing four times as much in energy costs compared to ongoing costs of energy from the electricity grid.

Other solutions, such as the use of renewable energy, can also add significant expense; solar panels and hydrogen generators result in additional upfront cost and increased yearly operating expenses.[127] Some markets in Europe also experience less stable electricity networks in rural areas compared to urban areas. This can result in about 70% of field interventions for cell sites being related to power issues, further increasing the cost per site in rural areas.[128]

Mobile network operators also experience challenges accessing the chosen location of a site due to a lack of roads. This may require the construction of an access road, either temporary or permanent, to be built for heavy machinery and engineers to access the site.

Operation and maintenance costs

Due to the greater sparseness in population and cell sites, maintenance costs per site tend to be higher in rural areas, as engineers are able to cover fewer sites. For instance, in Romania, the distance between maintenance depots and remote cell sites is around 80km, and engineers can only cover half as many sites as in urban areas.[129] This challenge can be exacerbated by the need to provide similar service levels and response times in rural and urban areas, which introduces inefficiencies in the distribution of maintenance staff around the country. For instance, where there are sites in hard to reach areas, such as mountains and small islands, the network operator may require engineers to locate within a specified area so that they are available should there be an issue with a site.

These challenges also affect fixed network operators for whom maintaining agreed service levels in rural areas is more costly per connection than in urban areas. Greater travel distances between maintenance jobs requires more maintenance staff per connection due to the need to have engineers located in rural areas for ease of access. This means that they are not as efficiently utilised compared to urban areas in which more maintenance jobs can be completed each day due to shorter inter-job travel times.

Identifying a fault can also be harder because of the longer access lines to rural premises.[130] This increases the staff maintenance cost per connection as more time is needed to identify and fix the fault.

Maintenance issues can also be exacerbated by weather conditions, which can in turn lead to higher costs. Adverse weather conditions, such as rain resulting in flooding or wind causing damage to towers and poles, are a common driver of spikes in rural network repair and maintenance. In addition to difficulties accessing the civil infrastructure to fix issues caused by the weather, it is often more challenging than in normal conditions due to the extra tasks involved, such as pumping water out of the duct before fixing the cabling. These issues can be more frequent in rural areas where flooding is more common, and repairs can take twice as long on average to fix.[131]

Site rental charges

In most instances, mobile network operators rent a base station site from a landlord, often rooftops in urban areas and land in rural areas. While land values are traditionally higher in urban areas, site rentals in rural communities can be as high as in urban areas, in part due to increased bargaining power of large landowners, who may own all the land for potential sites.

Planning permissions

In addition to impacting coverage and the number of sites, planning permission processes and more complicated rights of way access can lead to longer lead times, effort and expense spent on planning network build. Planning applications in rural areas can take over a year and, in some countries, the failure rate can be as high as 20%. This can be two to five times as long as the approval process in urban areas that can sometimes take months rather than a year.[132]

The additional time taken in rural areas can be due to changing the permitted land use from agriculture to building and property rights can be less clear in rural areas than urban in some countries. This can be further complicated by varying processes and resourcing levels amongst local authorities, which can in turn add time and increase the error rate of applications. This slows down rollout in rural areas, which can delay the generation of revenue, as well as adding to the cost of building a new site.

Rural backhaul expansion - drivers of relatively higher costs

Backhaul connectivity to rural mobile network sites has traditionally been provided using microwave links, as they could meet the capacity requirements needed at a lower cost than fixed fibre links. However, microwave backhaul has several limitations, which could become constraints on the development of 5G networks:[133]

- **Capacity:** Multi-band systems enable high-capacity wireless to backhaul over distances of up to 7 km. Beyond this, wireless backhaul solutions rely on traditional microwave spectrum, which is only capable of handling single-gigabit traffic. This will limit the available speeds to individuals based on network demand and could be especially relevant for services with high peak capacities such as automated transport in rush hour.
- **Latency:** Some 5G use cases require sub-10 ms end-to-end latency, which implies a latency of less than 2 ms across the backhaul network. Depending on the spectrum frequency and network design, this is not always possible with wireless backhaul.
- **Risk of interference:** Wireless backhaul can be prone to interference between cell sites using the same spectrum bands. This could become increasingly problematic as operators densify mobile networks, which puts cell sites in closer proximity.

Spectral attenuation: The shift to higher-frequency spectrum for wireless backhaul potentially constrains the ability of operators to meet enhanced reliability requirements of 5G. While frequencies below 13 GHz are largely unaffected by environmental conditions, higher-frequency spectrum has weaker propagation characteristics and is more susceptible to atmospheric effects and rain fade.

These challenges mean that in order to enable 5G uses cases requiring faster speeds and low latencies, rural sites will need to be connected with fibre backhaul. As well as impacting the cost of building new sites, the increased costs could also make the economics of rolling out enhanced connectivity to existing sites even more challenging.

This is particularly an issue in countries with large rural areas, mountainous geography and islands due to the longer distances, construction difficulties and the need for submarine cables (for example for islands and remote rural coastlines). Microwave backhaul can be over 15% cheaper than fibre over a 10km transmission.[134] In Romania, the average rural sites would require 15km of fibre, and to rollout their own fibre which could cost around EUR 83,000 in CAPEX and EUR 450/month in recurring costs such as pole rental. For the smallest municipalities in Spain, it is estimated that costs to connect a site with fibre could be as high as EUR 200,000.

Case Study: Greece

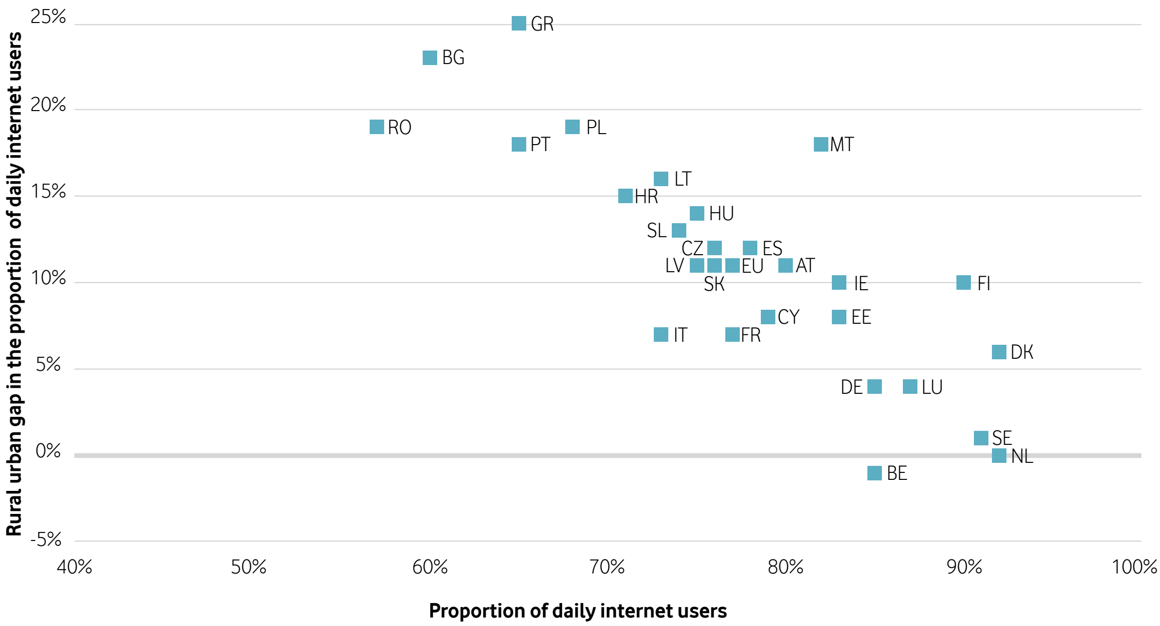
The combination of 200 populated islands, and high levels of network demand in the tourist season mean that network capacity needs to be very high, relative to traditional demand. Rural sites can have up to 4TB of traffic/month during summer, compared to only 1.7TB out of the tourist season. This necessitates the need for fibre backhaul and submarine cables which means backhaul costs from fibre can be 3-5x higher than the EU average.

Source: Based on Vodafone Opco market data

Demand-side considerations

Compounding the supply-side effects on networks costs in rural areas, there are also demand-side challenges to the economics of rural networks. Digital usage is much lower in rural communities; on average, 70% of internet users in EU rural areas say that they use the internet daily, compared to 81% of urban internet users. However, this urban-rural gap is much more pronounced in member states characterised by lower levels of internet usage. For instance, adults living in rural areas of Greece were 25 percentage points less likely to make daily use of the internet in 2019 when compared with their counterparts living in cities.[135]

Figure 23: Rural urban gap in the proportion of daily internet users (y-axis) against the overall proportion of daily internet users, 2019[136]



Source: Eurostat

The low levels of digital usage mean demand and potential revenue generated are lower in rural communities. For instance, the mobile sites in rural areas with the lowest levels of traffic can have 20 to 50 times less traffic than the average suburban site.[137] The rest of this section examines the key drivers that lead to lower levels demand and revenue in rural communities.

Income levels

Income has been found to be a key determinant of digital adoption.[138] In this context, median incomes in rural areas are 10% below the average across the whole of the EU and, in Romania, are 75% below the average.[139] Markets with lower rural incomes are likely to see reduced demand for enhanced connectivity, implying reduced returns on network investment.

Demographics

Rural communities are traditionally comprised of demographic groups with lower levels of digital use, such as the elderly. Across the EU, 22% of citizens in predominately rural communities are over 65, compared to only 18% in predominately urban areas.[140] In 2019, those aged 65-74 were three times more likely to have never used the internet relative to the total adult population aged 16-74.[141] Therefore demand for fast connectivity and large data packages is likely to be lower amongst older age groups, thus reducing the revenues and overall business case for rural deployment.

Similarly demand for enhanced connectivity among businesses with older employees may be constrained as they cannot adopt digital technologies due to a lack of digital skills among the workforce.[142]

Demand uncertainty

While general demand uncertainty is reducing due to increased customer demand for fast connectivity, there are rural areas in Europe that do not have any access to broadband.[143] Across the whole of the EU, 4% do not have access to speeds above 2Mbps, with much higher rates in Poland (31%) and Lithuania (15%). People in these areas are less likely to have experience in the use cases and benefits of connectivity, therefore may be less quick to take up services when they become available. From the perspective of an operator making significant network investments, demand uncertainty compounds the challenging economics of rural networks.

Alternative technologies for rural connectivity

Given the high cost of developing fixed and mobile access networks, operators and governments are considering alternative technologies. This section focusses on FWA and also gives an overview of satellite technology.

Fixed wireless access

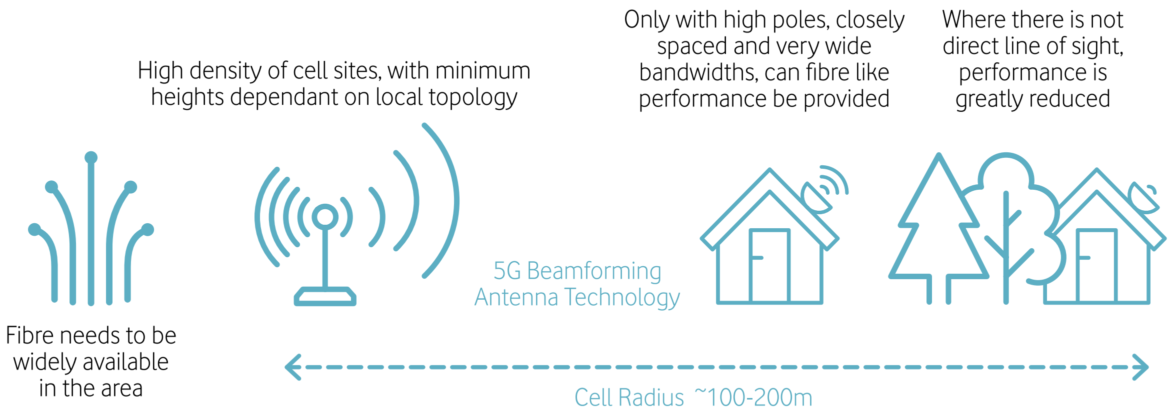
FWA provides an alternative to fixed networks and replaces the fibre or copper line in the access network with high frequency spectrum, using a mobile connection between a cell site and an antenna installed at a subscriber's premises.

By reducing the need to construct civil infrastructure and lay fibre, deploying FWA can be much more efficient than FTTP and can significantly reduce the cost of providing very high capacity connectivity in rural areas.

It is estimated that FWA can reduce the cost of last mile connectivity by 40% relative to FTTP.[144] Furthermore, FWA can speed up the deployment of very high capacity connectivity, allowing rural communities to access gigabit capable networks much earlier than might be the case with FTTP. In addition, FWA will not lock communities into current technology; in due course it may be upgradeable to 6G, allowing for possible further network developments, or to FTTP.

FWA however, is not a perfect substitute of FTTP. To provide similar speeds and capacity as fibre, high frequency, 26Ghz spectrum is used. High speed frequencies can be sensitive to adverse weather conditions. In addition, FWA networks require line of sight to the subscriber's antenna, which depending on the topology can require dense network deployment. This may reduce the cost advantage to FTTP. For instance, in Australia, NBNCo's rural FWA deployment found that cell sites could only reach 20% of premises within their theoretical range of 14km due to difficulties in obtaining line-of-sight.[145] Line of sight requirements can also mean that a technician would be needed to install the antenna at the end user's premise. Lower frequency, 3.5Ghz spectrum can alternatively be used to alleviate the above challenges. This however will limit somewhat the capacities and speeds that can be offered.

Figure 24: Illustration of an FWA network and the potential challenge



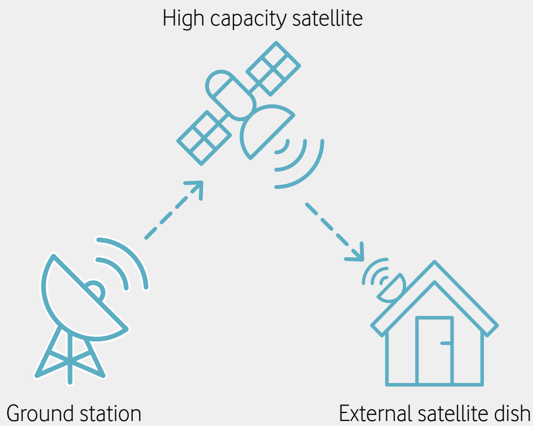
Source: European Commission (2021); Analysys Mason (2016)

Satellites

Satellite technology can also offer an alternative solution for rural connectivity, with some companies planning deployments of low earth orbit satellite constellations to provide connectivity. High frequency spectrum from 18.3GHz to 31GHz is used to connect a satellite dish at a subscriber's premises, with a high throughput satellite which connects to a ground station at the edge of the core network.

The incremental cost of serving a subscriber using satellite technology is primarily driven by the average fixed cost of installing a satellite dish and equipment at the customer premise, estimated as EUR 350 in the EU.

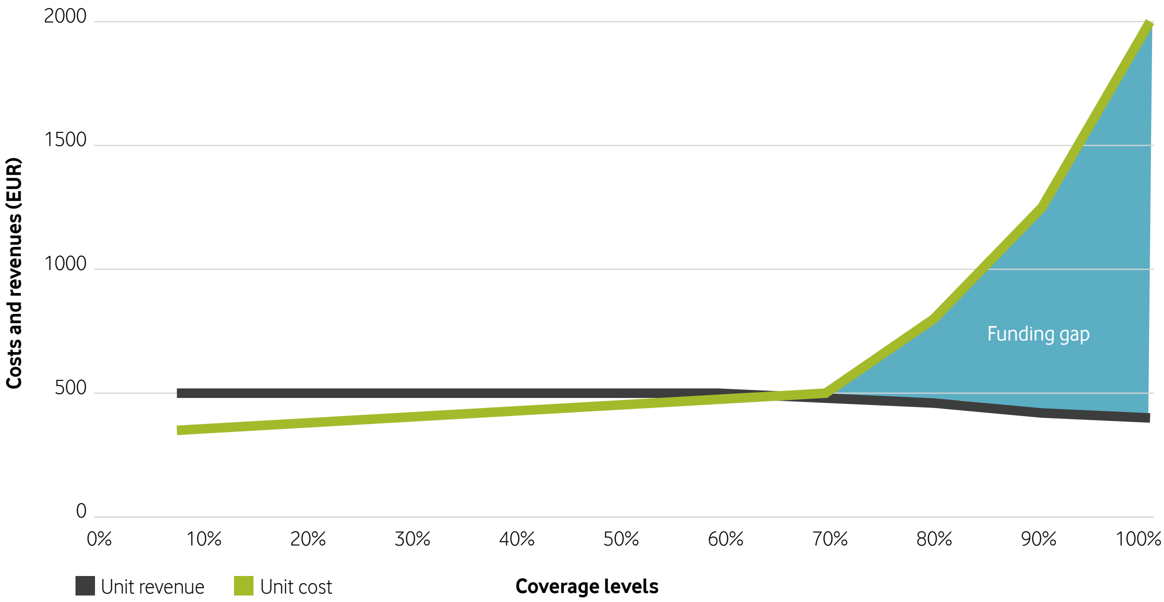
While this cost is much lower than for serving an extra customer using a fixed network, the network is much more limited in terms of speed and capacity. Currently in the EU, satellites can provide speeds of 22Mbps for download and 6Mbps for upload, and 50Mbps and 10Mbps for businesses. Similarly, latency is much greater, typically up to 500–700ms, due to the large distances between the satellite and both the ground station and end user. Furthermore, when satellite capacity is rented from a commercial provider, OPEX costs can be much greater than traditional fixed networks. While new satellites, with greater capacity, could improve network quality, this would also be relatively expensive.



Overall operator business case

This section has examined the key drivers that make the economics of rural connectivity challenging. As networks expand from urban to suburban to rural to very remote regions the commercial business case tends to gradually weaken and indeed it can become non-profitable depending on the local conditions. As illustrated in Figure 25 then, although it is commercially profitable to cover the first deciles of the population is urban and suburban areas, it might not be so when population coverage extents to the last deciles in remote and some rural areas.

Figure 25: Illustrative example of the funding gap for rural coverage at the highest levels of coverage



Source: Illustrative example

The next section of this report discusses potential policies tools that may reduce the cost of rolling out high capacity networks in rural areas.

Potential policy tools

As discussed earlier in this report, enhanced rural connectivity can enable Europe's vision for socio-economic progress and can help deliver more balanced sustainable growth for everyone. The potential social benefits of connectivity are large and support broader progress on rural development. However, the costs of deploying networks to some rural areas are likely to be higher than what citizens and businesses are willing to pay for connectivity. Therefore, commercial incentives alone may be insufficient to drive network deployment in these areas.

As a result, there is a strong case in some rural areas for government intervention to unlock the social benefits arising from enhanced connectivity. There are a wide array of policy tools that governments can use to support the deployment of enhanced connectivity in rural areas. This section summarises the policies and responses that governments have considered.

The appropriate mix of policies will vary by country, in line with the predominant barriers to network deployment within each country and the reforms that have already been implemented. The level of the policy intervention will also have to take into account the expected costs and benefits.

Policymakers will need to understand the trade-off between delivering better connectivity in more remote regions and the costs of deployment. These costs can be spread out between public and private investors supported by enabling initiatives and incentive mechanisms that close the funding gap. Finally, to fully realise the benefits of rural connectivity, complementary demand-side policies such as vocational programmes to increase digital skills and awareness of opportunities, or vouchers for digitalisation programs to support SMEs will be required to encourage the adoption of technologies in rural areas.[146]

Land access and planning restrictions

Improving access to land and reducing constraints on right of way permits and planning permission processes can help reduce the marginal cost of rolling out both fixed and mobile networks in rural areas by reducing operator planning and deployment costs. Streamlining access and planning processes may also enable faster deployment of networks, leading to quicker revenue realisation for operators and improving the investment case for network deployment. Examples include:

- **Improving permit application processes:** Making it easier for operators to apply for, and receive, permits to construct new fibre routes and to build new cell sites can reduce the time and cost involved in planning both fixed and mobile network deployments:
    - **For fixed networks,** increasing the speed and reducing the cost of rights of way can help reduce operator costs and allow networks to be expanded faster; in some member states, such as the Netherlands, rights of way are free of charge.[147]
    - **For mobile networks,** simplification and acceleration of planning process can help optimise the number of RAN cell sites required, as sites can be placed closer to locations required for optimal coverage.
- **Increasing maximum tower heights:** Allowing mobile network operators to build higher towers in certain areas, extends the range over which a network signal can propagate and thus can make them a more viable investment while it also improves signal quality. For example, increasing the height of a mast from 15m to 20m can boost the

coverage it provides by 10%. Increasing the mast height from 20m to 25m can increase its coverage by a further 19%.[148]

- **Alignment with international EMF limits:** Aligning EMF levels to limits set out in ICNIRP Guidelines can help improve the propagation of mobile networks and can reduce the number of cell sites needed to cover a certain geographic area. Setting EMF limits at lower levels also constrains the ability of mobile operators to share their radio networks.[149]

Naturally, land access and reducing deployment restrictions needs to be sensitive to the preferences of communities and landowners, in order that all can benefit from expanded connectivity in a fair and transparent way.

Access to physical infrastructure

Extensive fibre networks not only provide high capacity fixed connectivity for homes and businesses, but also provide the backhaul connectivity required by mobile networks.

Existing civil infrastructure owned, for example, by telecoms operators, other network utilities, local governments or road operators, has been utilised to facilitate the rollout of fibre in rural areas. Enabling access to this infrastructure, such as underground ducts or existing roadside poles, can reduce the cost of deploying new networks, as the cost of sharing existing infrastructure can often be lower than the cost of building new civil infrastructure. Such infrastructure access can also provide the flexibility for operators to configure their network topology to best suit their own needs. However, the costs and benefits of accessing existing physical infrastructure depend on several market-specific factors, such as the cost of accessing the infrastructure both to the owner and access seeker and the available capacity to share the infrastructure.

Governments can help facilitate sharing of existing physical infrastructure by improving the coordination and – where appropriate – sharing of information between infrastructure owners and access seekers on planned and future deployments. For instance, governments can support the sharing of information on the location and condition of ducts and poles through a single open access digital information point. This centralised source of information can help operators plan and cost the deployment of networks in rural areas, by enabling them to identify opportunities to share existing physical infrastructure. Governments can also provide access to public infrastructure, such as streetlights and government-owned buildings and land to support rural network deployments.

Case study example: UK Shared Rural Network

The Shared Rural Network (SRN) was created by industry and Government with the objective to deliver reliable broadband to 95% of the UK by improving 4G services in remote locations. Grey spots will be addressed by Mobile Network Operators (MNOs) who have committed to building new sites, updating their existing sites, and to sharing infrastructure. White spots should be addressed by the development of new sites, which will be built jointly by the MNOs and overseen by Digital Mobile Spectrum Limited.

Source: Vodafone; Shared Rural Network

Mobile network and infrastructure sharing agreements

As discussed earlier in this report, the cost of building and maintaining new mobile sites, relative to the commercial benefits, is one of the key barriers or constraints on extending mobile coverage in rural areas. Various forms of network sharing can reduce the number of sites needed by all operators and can therefore reduce the cost of rolling out rural mobile coverage. Sharing can be active or passive, as appropriate to the local conditions.[150]

Through the sharing of sites, operators can realise CAPEX savings, as they share the cost of building new sites and backhaul connectivity, as well as ongoing OPEX savings from sharing the cost of power and maintenance. While the level of savings from sharing varies, savings of as much as much as 40% of site CAPEX and 33% for OPEX can be realised.[151,152] It is worth mentioning that in addition to the costs savings, the deduplication of networks can bring other collateral efficiencies such as lower energy usage. It is worth mentioning that in addition to the costs savings, the deduplication of networks can bring other collateral efficiencies such as lower energy usage.

While infrastructure sharing can have positive benefits, there can be concerns that extensive sharing, especially nationwide active sharing, could reduce levels of competition between the operators involved. Those operators may have less incentive to invest or less scope to differentiate on network quality, and thus it is important for policies that encourage sharing to also ensure that competition is maintained.[153] Finally, there are also operational and logistical challenges involved with network sharing that operators must overcome to integrate their network components.

Case study example: Active sharing in Italy

In Italy, Vodafone has created an active network sharing partnership for 4G and 5G with Telecom Italia Group. They also agreed to merge their passive tower infrastructure, comprising 22,000 towers. This partnership is expected to enable Vodafone and Telecom Italia to deploy 5G more quickly, and over a wider geographic area.

Source: Vodafone (2019) Source: European Commission (2018)

Spectrum licences

Timely release of licensed spectrum is essential to achieving efficient rollout of mobile networks; as with greater access to spectrum, in particular low frequency spectrum, operators may need to build or access fewer sites to improve mobile coverage.

For 5G, mid and high frequency spectrum delivering low latency and high speeds can be paired with low frequency spectrum (e.g. 700 MHz) which is well suited for providing mobile coverage over wide areas as well as indoors. This has the potential to enable the greatest number of use cases, such as IoT enabled precision farming and connected mobility, to be rolled out across rural areas.

Greater access to low frequency spectrum can also reduce the number of sites that operators need to build to provide coverage in a given area, thereby reducing the cost of extending coverage. As a result, providing licensed access to these frequencies can help improve the level of mobile coverage, including mobile voice and data coverage in rural areas, as well as in buildings and in other harder-to-reach places.[154] For example, the timely award of licensed 700 MHz spectrum has the potential to enable the rollout of 5G mobile services outside of urban areas.[155]

The design and award of spectrum licences also has the potential to impact on operators' ability and incentives to invest in rural networks by:

- Ensuring that any conditions attached to licences (e.g. minimum service requirements, coverage obligations) are well-defined, take into account commercial incentives and do not distort competition, which may otherwise have the unintended effect of reducing network deployment in remote rural areas.

- Implementing spectrum licensing and allocation mechanisms that aim to achieve efficient spectrum allocation rather than maximise revenue such as extension of licence terms. This may be considered as part of a wider package of policies designed to incentivise non-distortionary network investment. While this may not directly and specifically improve the commercial case for rural network deployment, it may facilitate greater overall investment in the sector, increasing the resources available to support network expansion.

Wider enablers

Rural digitalisation has clear benefits and is potentially transformational to rural communities. However, the way in which this evolves with the introduction of enhanced connectivity and digitalisation enabling new ecosystems is hard to predict. In order to maximise the benefits and potential of rural digitalisation, there are overarching enablers and initiatives that policymakers may consider.

- **Promoting partnerships between policymakers and across industry stakeholders:** European governments can work together with local authorities and industry stakeholders to understand the specific challenges and opportunities within different regions. This collaboration can help to allocate funding and set out complementary policies to ensure that the potential benefits of connectivity are realised. Infrastructure owner/operators and policymakers must work in partnership to overcome other barriers to network deployment. For instance, improving transport and electricity networks in remote communities can help reduce the costs of rural networks. Further, businesses will require support from policymakers in making sure that infrastructure and labour skills are available, and local policymakers will need to translate broad digitalisation targets into local policies.

- **Technology neutral policies and initiatives:** Given the uncertainty around the digitally enabled ecosystems that will spur rural development, it is important that policy and guidance on support remain technologically neutral. This will enable policymakers and industry stakeholders to deploy the appropriate technology (e.g. fibre, 5G, FWA, etc.) that best serves the conditions in the local area to maximise benefits. This will enable more efficient delivery against overall connectivity objectives and have lower risk of distorting markets. For example, current state aid guidelines provide clearer guidance in relation to investment in fibre networks than they do for investments in 5G connectivity.

- **Enhancing digital skills in rural areas:** The extent and distribution of digital skills will be a key determinant of the success of digital transformation and the extent to which benefits can be shared across European society. Just 48% of citizens in rural areas have basic digital skills, compared to 62% in cities. Therefore, upskilling rural citizens is essential preparation for the opportunities of digital transformation, enabling the creation of new jobs and access to new markets. This extends not only to citizens, but also intermediaries of digital technologies such as teachers, medical staff, civil servants and others involved in public services.

Conclusion

Europe, with its commitments in the Recovery and Resilience Facility, has a unique opportunity to digitalise the European economy. Funding to support rural connectivity will be essential in ensuring that the digital divide does not widen, leaving behind the 30% of citizens living in rural communities as the rest of Europe undergoes digital transformation.

The benefits of rural digitalisation are potentially large. Enhanced connectivity can deliver development in all pillars identified in the long-term vision for rural areas and is key to achieving the Digital Decade targets. More than this, enhanced connectivity and digitalisation will transform rural communities, enabling new ecosystems to emerge and thrive and more people to enjoy the benefits of rural life.

However, the costs of expanding and enhancing connectivity to rural areas and achieving the overall connectivity targets, can also be significant. Although policymakers recognise the need to provide support, such as financial incentives for networks rollout and cost reduction measures, such support will vary by country. For support to be effective and efficient, policymakers need to:

- Evaluate the costs and, just as importantly, identify and assess the social benefits of enhanced connectivity to rural areas, taking into account the particular characteristics of the rural areas being considered (i.e. types and sectors of businesses, existing provision of public services, existing level of connectivity). This should also consider the deployment of different connectivity technologies.

- Consider the supporting policies and wider enablers to overcome barriers to technology adoption such as lack of digital skills. Policymakers should look to coordinate and collaborate across different levels of government and with industry stakeholders in order to deliver enhanced connectivity.

The above approach may reveal potential trade-offs that national governments may have to make in delivering against the EC's ambitious connectivity targets. It is important, though, that policymakers ensure that digitalisation across rural areas, and the whole of Europe, is achieved inclusively and sustainably. The digital transformation to be realised over the next decade will not achieve its full potential if parts of European society are left behind without access to, or the ability to make the most of, digitalisation.

Endnotes

1 https://www.europarl.europa.eu/RegData/etudes/BRIE/2017/599333/EPRS_BRI(2017)599333_EN.pdf

2 https://www.europarl.europa.eu/RegData/etudes/STUD/2019/629209/IPOL_STU(2019)629209_EN.pdf

3 Rural development – long-term vision for rural areas (europa.eu)

4 https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

5 https://digital-strategy.ec.europa.eu/en/library/broadband-handbook-facing-challenges-broadband-deployment-rural-and-remote-areas

6 https://s3-eu-west-1.amazonaws.com/govieassets/8526/291c26d4eb-d54965999eaeb591a216c1.pdf

7 https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

8 NGA coverage includes VDSL, VDSL2 Vectoring, FTTP, DOCSIS 3.0, DOCSIS 3.

9 https://etno.eu/news/all-news/704-etno-bcg.html

10 Based on Vodafone Opco market data

11 https://www.snstelecom.com/5g-based-fwa-fixed-wireless-access-a-1-billion-opportunity-says-sns-research-report

12 https://ec.europa.eu/info/strategy/priorities-2019-2024/new-push-european-democracy/long-term-vision-rural-areas/eu-rural-areas-numbers_en

13 https://www.europarl.europa.eu/factsheets/en/sheet/106/financing-of-the-cap

14 European Commission, Long-term vision for rural areas

15 https://europa.eu/european-union/about-eu/priorities_en

16 European Commission, The Digital Compass

17 https://ec.europa.eu/digital-single-market/en/broadband-strategy-policy#:~:text=The%20three%20main%20strategic%20objectives,for%20all%20European%20households%2C%20and

18 https://ec.europa.eu/digital-single-market/en/digital-economy-and-society-index-desi

19 https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_20_1999

20 https://eur-lex.europa.eu/resource.html?uri=cellar:12e835e2-81af-11eb-9ac9-01aa75ed71a1.0001.02/DOC_1&format=PDF

21 https://www.eurofound.europa.eu/publications/report/2020/living-working-and-covid-19

22 https://www.tcs.com/content/dam/tcs/pdf/perspectives/covid-19/business-impact-survey-2020.pdf

23 https://www.consilium.europa.eu/en/press/press-releases/2021/05/31/green-light-from-all-member-states-for-eu-recovery-spending/

24 https://ec.europa.eu/info/strategy/priorities-2019-2024/new-push-european-democracy/long-term-vision-rural-areas_en

25 http://5gobservatory.eu/wp-content/uploads/2021/04/90013-5G-Observatory-Quarterly-report-11-2.pdf

26 https://ec.europa.eu/info/sites/default/files/economy-finance/assessment_of_economic_and_investment_needs.pdf

27 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12525-Long-term-vision-for-rural-areas/public-consultation_en

28 Vodafone Institute for Society and Communications (2021), Digitising Europe Pulse #5: Focus on the rural-urban digital divide

29 https://www.europarl.europa.eu/doceo/document/AGRI-AD-652568_EN.pdf

30 https://ec.europa.eu/eurostat/databrowser/view/SBS_SC_SCA_R2__custom_913034/default/table?lang=en

31 https://ec.europa.eu/growth/smes/sme-strategy_en

32 Equivalized income is a measure of household income that takes account of the difference in a household's size and composition. https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Equivalised_income#:~:text=Equivalised%20income%20is%20a%20measure,all%20household%20sizes%20and%20compositions

33 https://appsso.eurostat.ec.europa.eu/nui/show.do

34 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12525-Long-term-vision-for-rural-areas/public-consultation_en

35 https://ec.europa.eu/eurostat/databrowser/view/ilc_di17/default/table?lang=en

36 https://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/495840/IPOL-TRAN_ET(2013)495840_EN.pdf

37 https://local.gov.uk/why-digital-connectivity-matters#:~:text=Research%20by%20the%20Federation%20of,the%20success%20of%20their%20business.&text=Studies%20have%20also%20shown%20mobile,higher%20GDP%20and%20increased%20employment.

38 https://www.vodafone.com/sites/default/files/2020-10/sme-digitalisation.pdf

39 https://about.fb.com/wp-content/uploads/2020/11/Deloitte-Digital-Tools-in-Crisis-and-Recovery-SMB-Report-Oct-2020.pdf

40 https://desira2020.eu/wp-content/uploads/2020/11/Practice-Abstract-Aurea4Rural_UNIPI.pdf

41 https://s3-eu-west-1.amazonaws.com/govieassets/8526/291c26d4eb-d54965999eaeb591a216c1.pdf

42 http://smartfarming.ie/wp-content/uploads/2017/10/SFRF.pdf

43 https://www.sciencedirect.com/science/article/pii/S1573521418302100

44 https://hbr.org/resources/pdfs/tools/Verizon_Report_June2014.pdf

45 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734857/BDUK_SF_EVAL_ANNEX_B_ECONOMIC_IMPACTS.pdf

46 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734855/Superfast_Integrated_Report.pdf

47 https://www.econstor.eu/bitstream/10419/168484/1/Hasbi.pdf

48 https://www.oecd.org/coronavirus/policy-responses/productivity-gains-from-teleworking-in-the-post-covid-19-era-a5d52e99/#:~:text=Telework%20can%20improve%20firm%20performance,focused%20work%20or%20less%20absenteeism

49 http://conference.iza.org/conference_files/DATA_2019/kostol_a8219.pdf

50 https://www.openreach.com/fibre-broadband/full-fibre-impact

51 https://journals.sagepub.com/doi/10.1177/0018726717713828

52 https://ec.europa.eu/info/strategy/priorities-2019-2024/new-push-european-democracy/long-term-vision-rural-areas/eu-rural-areas-numbers_en

53 https://www.gov.ie/en/publication/4c236-our-rural-future-vision-and-policy-context/

54 See https://ec.europa.eu/digital-single-market/en/news/study-socio-economic-impact-bandwidth-smart-20100033 and https://www.vodafone.com/sites/default/files/2021-02/digitalisation-an-opportunity-for-europe.pdf for summaries of the literature

55 Country variations may be largely driven by the relative importance of agriculture to the overall economy. https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG#

56 https://www.google.com/search?q=more+than+40%25+of+rivers+and+coastal+water+bodies+are+affected+by+diffuse+pollution+from+agriculture&rlz=1C1GCEA_enGB901GB903&oq=more+than+40%25+of+rivers+and+coastal+water+bodies+are+affected+by+diffuse+pollution+from+agriculture&aqs=chrome..69i57.9604j0j9&sourceid=chrome&ie=UTF-8

57 https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG#

58 https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en

59 https://ec.europa.eu/environment/enveco/resource_efficiency/pdf/studies/issue_paper_digital_transformation_20191220_final.pdf

60 https://www.annualreviews.org/doi/pdf/10.1146/annurev-resource-100518-093929

61 https://ec.europa.eu/environment/enveco/resource_efficiency/pdf/studies/issue_paper_digital_transformation_20191220_final.pdf

62 https://ec.europa.eu/energy/topics/markets-and-consumers/smart-grids-and-meters_en#smart-metering-benefits

63 https://www.gsma.com/wp-content/uploads/2019/04/The-5G-Guide_GSMA_2019_04_29_compressed.pdf

64 https://digital-strategy.ec.europa.eu/en/library/fibre-most-energy-efficient-broadband-technology

65 An important caveat to this is that, with better and more efficient networks, data usage and storage are expected to increase above the current levels, requiring greater energy, which will to some extent negate these potential benefits. This is known as the rebound effect.

66 https://www.vodafone-institut.de/wp-content/uploads/2021/06/CT_Homeworking-report-June-2021.pdf

67 https://www.europarl.europa.eu/RegData/etudes/STUD/2021/662904/IPOL_STU(2021)662904_EN.pdf

68 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/257006/UK_Broadband_Impact_Study_-_Impact_Report_-_Nov_2013_-_Final.pdf

69 Openreach (2018) The Impact of High-Speed Broadband for Communities

70 https://ati.ec.europa.eu/reports/technology-watch/technology-focus-cloud-computinghttps://ec.europa.eu/environment/enveco/resource_efficiency/pdf/studies/issue_paper_digital_transformation_20191220_final.pdf

71 https://ati.ec.europa.eu/sites/default/files/2021-02/AT%20Watch%20Cloud.pdf

72 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12525-Long-term-vision-for-rural-areas/public-consultation_en

73 https://ec.europa.eu/eurostat/documents/3217494/11348978/KS-HA-20-001-EN-N.pdf/f1ac43ea-cb38-3ffb-ce1f-f0255876b670?t=1601901088000

74 Based on total EU27 population aged over 16 and proportion of population in rural areas and cities.

75 https://www.europarl.europa.eu/RegData/etudes/BRIE/2017/599333/EPRS_BRI(2017)599333_EN.pdf

76 https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20200207-1

77 Vodafone Institute for Society and Communications (2021), Digitising Europe Pulse #5: Focus on the rural-urban digital divide

78 https://ec.europa.eu/health/ehealth/home_en#:~:text=Digital%20health%20and%20care%20refers,lifestyle%2Dhabits%20that%20impact%20health

79 https://ec.europa.eu/digital-single-market/en/news/study-socio-economic-impact-bandwidth-smart-20100033

80 https://www.ajmc.com/view/improving-vaccine-allocation-through-scheduling-data-solutions

81 EuropeConnected_eHEALTH.pdf (vodafone.com)

82 https://ec.europa.eu/health/sites/default/files/ehealth/docs/2018_provision_marketstudy_telemedicine_en.pdf

83 https://www.gsma.com/iot/wp-content/uploads/2013/06/Socio-economic_impact-of-mHealth_EU_14062013V2.pdf

84 Mhealth is a subset of e-health referring to mobile or portable devices used in healthcare

85 https://www.gsma.com/iot/wp-content/uploads/2013/06/Socio-economic_impact-of-mHealth_EU_14062013V2.pdf

86 https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/public-sector/deloitte-nl-shaping-the-future-of-european-healthcare.pdf

87 Note in traditional cost benefit analyses, value of a life year or value of a prevented fatality are used. However, as most health analyses undertake cost effectiveness analyses that base the benefits on increases in QALYs, this approach is recommended.

88 Blended learning is an approach that combines online education services with traditional classroom methods.

89 Vodafone Institute for Society and Communications (2021), Digitising Europe Pulse #5: Focus on the rural-urban digital divide

90 https://ec.europa.eu/health/ehealth/home_en#:~:text=Digital%20health%20and%20care%20refers,lifestyle%2Dhabits%20that%20impact%20health.

91 http://motu-www.motu.org.nz/wpapers/17_03.pdf

92 https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en

93 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869263/The_impact_of_undergraduate_degrees_on_lifetime_earnings_research_report_ifs_dfe.pdf

94 https://www.cairn.info/revue-reflets-et-perspectives-de-la-vie-economique-2012-3-page-73.htm

95 Grossman, M. (2006), 'Education and non-market outcomes', in E. Hanushek and F. Welch, eds., Handbook of the Economics of Education. Amsterdam: North Holland, pp. 576-633

96 https://ec.europa.eu/commission/presscorner/detail/en/QANDA_20_1197

97 DESI Index

98 https://digital-strategy.ec.europa.eu/en/policies/digital-skills-and-jobs

99 https://ec.europa.eu/info/sites/default/files/economy-finance/eb054_en.pdf https://wiiw.ac.at/breaking-through-the-digital-ceiling-ict-skills-and-labour-market-opportunities-dlp-5597.pdf

100 Haveman, R. and B. Wolfe (1995), 'The Determinants of Children's Attainments: A Review of Methods and Findings', Journal of Economic Literature, 33:4, 1829-1878

Grossman, M. (2006), 'Education and non-market outcomes', in E. Hanushek and F. Welch, eds., Handbook of the Economics of Education. Amsterdam: North Holland, pp. 576-633

101 https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/public-sector/lu-government-trends-2020.pdf

102 https://ec.europa.eu/esf/transnationality/filedepot_download/1671/1686

103 https://digital-strategy.ec.europa.eu/en/policies/egovernment#:~:text=eGovernment%20and%20digital%20public%20services,-The%20European%20Commission&text=Effective%20eGovernment%20can%20provide%20a,of%20citizens%20in%20political%20life.

104 https://www.sciencedirect.com/science/article/pii/S2210670718312630

105 https://ec.europa.eu/employment_social/soc-prot/soc-incl/final_joint_inclusion_report_2003_en.pdf#page=9

106 https://www.europarl.europa.eu/RegData/etudes/BRIE/2017/599333/EPRS_BRI(2017)599333_EN.pdf

107 Cohesion Policy supporting rural areas and communities | Data | European Structural and Investment Funds (europa.eu)

108 https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689349/EPRS_BRI(2021)689349_EN.pdf

109 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12525-Long-term-vision-for-rural-areas/public-consultation

110 Ashmore, F., J Farrington & S. Skerratt (2015): "Superfast Broadband and Rural Community Resilience: Examining the rural need for speed" in Scottish Geographical Journal (131: 3-4) pp265-278

111 https://cordis.europa.eu/programme/id/H2020_CULT-COOP-08-2016

112 https://www.eurofound.europa.eu/surveys/european-quality-of-life-surveys

113 Superfast_Integrated_Report.pdf (publishing.service.gov.uk)

114 https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_sk_dskl_i&lang=en

115 Cellular signals can struggle to penetrate through buildings (e.g. walls, windows) resulting in a loss or degradation of service. As a result, providing in-building coverage can be more challenging. Operators may deploy specific in-building solutions and deploy lower spectrum frequencies that are able to penetrate through buildings, in order to provide indoor coverage.

116 Note depending on the level of isolation between homes, the 'homes passed' separation point from the 'homes connected' portion of the network can be significantly different in cost for different areas. Therefore, costs to connect rural communities could still be very high, even once it is considered passed. https://ftthcouncil.eu/documents/Reports/2017/FTTH%20Council%20Cost%20Model%202017_final.pdf

117 https://nbi.ie/news/latest/2020/05/06/national-broadband-plan-to-be-completed-ahead-of-schedule-and-under-budget/

118 https://www.gov.ie/en/publication/c1b0c9-national-broadband-plan/

119 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_grids

120 GEOSTAT Population Grid based on census data, which is only generated every 10 years, therefore 2011 is the most recent version available.

121 ComReg, Meeting Consumers' Connectivity Needs

122 ComReg, Meeting Consumers' Connectivity Needs

123 https://ec.europa.eu/digital-single-market/en/cost-reduction-measures

124 https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/montagne/mount4.pdf

125 Based on Vodafone Opco market data

126 Based on Vodafone Opco market data

127 In Romania it was reported this could cost an additional EUR 50k in CAPEX and EUR 15k in additional yearly OPEX

128 Based on Vodafone Opco market data

129 Based on Vodafone Opco market data

130 Ofcom, 2020, Improving broadband and landline standards: A review of how Ofcom's service quality rules have affected Openreach's service level performance. Available at https://www.ofcom.org.uk/__data/assets/pdf_file/0033/195099/ex-post-evaluation-openreach-quality-of-service.pdf

131 https://www.ofcom.org.uk/__data/assets/pdf_file/0026/81557/openreach_-_quality_of_service.pdf

132 Based on Vodafone Opco market data

133 https://www.gsma.com/mena/wp-content/uploads/2020/10/200915-wireless-backhaul_Final.pdf

134 https://carrier.huawei.com/en/relevant-information/maxmizing-network-value/microwave-cost-effective-solution

135 https://ec.europa.eu/eurostat/statistics-explained/pdfscache/2549.pdf

136 https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

137 Based on Opco data

138 see e.g. Billon et al. 2008, Vicente and Lopez 2011 and Billion et al. 2016

139 Eurostat

140 https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=urt_pjangrp3&lang=en

141 https://ec.europa.eu/eurostat/statistics-explained/index.php/Ageing_Europe_-_statistics_on_social_life_and_opinions#Education_and_digital_society_among_older_people

142 OECD (2008). Developments in fibre technologies and investment. DSTI/ICCP/CISP(2007)4. Paris: OECD

143 Defined as speeds greater than 2Mbps

144 https://www.snstelecom.com/5g-based-fwa-fixed-wireless-access-a-1-billion-opportunity-says-sns-research-report

145 https://www.ofcom.org.uk/__data/assets/pdf_file/0027/95580/annex6.pdf

146 https://www.vodafone.com/content/dam/vodcom/files/vdf_files_2020/pdfs/sme-digitalisation.pdf

147 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52013SC0073&rid=8

148 https://www.ofcom.org.uk/__data/assets/pdf_file/0017/120455/advice-government-improving-mobile-coverage.pdf

149 Radio spectrum is used to provide communications services, including mobile phones, business radio, Wi-Fi, TV and radio. All uses of spectrum generate electromagnetic fields (EMF). There are international guidelines to help ensure services operate safely. The guidelines are published by the International Commission for Non-Ionising Radiation Protection (ICNIRP) and include limits for the safe level of EMF.

150 Passive sharing refers to the sharing of the mechanical elements of network infrastructure such as masts, sites, cabinets, power, and air conditioning. Active sharing is the sharing of electronic elements in access networks such as antennas and radio network controllers in mobile networks and optical line terminals and optical network units in fixed networks.

151 BEREC (2018); Report on Infrastructure sharing

152 Neumann and Plückebaum (2017); Mobile Network Sharing

153 https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8164-berec-report-on-infrastructure-sharing

154 The propagation characteristics of low frequency spectrum enables a single cell site to provide mobile coverage for a larger area than higher frequency spectrum.

155 EU member states are required to repurpose the 700 MHz frequency band for new mobile broadband use by 30 June 2020 (Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union).