CONSULTING

Report for Ericsson and Qualcomm

5G action plan review for Europe

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1 Abstract

This study was requested by Ericsson and Qualcomm and has been developed in collaboration with the 5G policy and technology teams at Ericsson and Qualcomm.

The aim of the study is to provide a detailed analysis of the costs and benefits of 'full 5G' deployments in Europe. The analysis focused on a series of possible use cases for 5G, beyond the initial enhanced mobile broadband (eMBB) services for consumers that many European mobile network operators (MNOs) have launched to date on top of 4G networks.

A full 5G deployment is envisaged to use the latest 5G specifications to drive fundamental changes in the way that mobile networks are built, using a 5G standalone architecture with network automation, virtualisation and tailoring of services via network slicing to match the functionality required by different industries (or verticals).

In this study, we set out to answer the following questions:

- Which uses and use cases of full 5G deployment might be the most relevant from a European market perspective, taking account of European policy priorities and the European industries that might benefit most from 5G capabilities around low latency, high reliability and massive machine-type connections?
- What are the social, environmental and economic benefits of extending 5G networks to deliver new uses and use cases, and what are the 5G network deployment costs to deliver these benefits?
- Is there an opportunity for European policy to shape future full 5G deployment and what are the key priorities for future 5G policy?

The focus of the study has been on innovative new use cases and the different environments that 5G is designed to support, rather than the speed and capacity increases 5G can provide for consumers using eMBB built on existing 4G mobile broadband (MBB). These new use cases, which include the use of ultra-reliable and low-latency communications, and massive machine-to-machine communication, will be supported by a move towards full (standalone) virtualised 5G networks.

Many of the benefits of new 5G use cases are yet to be realised on a large scale and much of the assessment of the impact of new use cases is based on limited published evidence to date. This study has referred to existing studies discussing the qualitative benefits of the new 5G use cases and we have also undertaken detailed bottom-up modelling of costs, and economic benefits, of delivering new 5G use cases in Europe.

The study aims to bring new insight to the debate around the value of 5G, by providing a detailed and robust cost–benefit analysis of selected new 5G use cases, to provide further quantitative estimates of the impact of 5G in shaping Europe's digital future.

2 Executive summary

The overall aim of the study has been to analyse the cost and benefits of 'full 5G' use cases in Europe, to help to support future development of European 5G policy, and potentially update the European 5G Action Plan (5GAP).

The existing 5GAP was defined in 2016. Current European 5G deployments are taking place within the context of 2016 5GAP targets:

- initial 5G networks are launched in Europe by 2020, and 5G coverage is promoted across urban areas, and main transport paths, by 2025
- several spectrum bands are being made available for 5G in Europe, meeting coverage and capacity requirements. In line with the 5G pioneer bands set out in the 5GAP:
  - bands below 1GHz and the 3.5GHz band are being deployed for 5G coverage and for capacity
  - higher bands (e.g. 26GHz) enable very high capacity in locations where traffic demand is highest, taking account of the diverse requirements for 5G use cases in different environments.

Our approach to the study has been to provide a cost–benefit analysis to inform the development of updated European 5G goals towards full 5G deployment (using standalone architectures, and addressing all 5G use cases), and to aid European economic recovery post 2020.[1] We have developed inputs and assumptions on 5G deployment and evolution towards full 5G that take account of published industry experience from 5G trials and initial deployments that have occurred after the 5GAP targets set in 2016, and reflect current technological trends of virtualisation, automation and end-to-end slicing.

Ericsson and Qualcomm commissioned Analysys Mason to conduct this study during March 2020 and the study was completed in September 2020.

2.1 Status of 5G deployment in Europe

Several countries in Europe have now launched initial 5G services, which are based on 4G infrastructures, and further networks are expected to launch later in 2020 and 2021. Of the European countries where 5G has already been launched, Finland has the highest population coverage (over 50%) whereas most countries are at coverage of 15–40%.

1 Economic recovery in Europe following the COVID-19 pandemic in 2020

Figure 2.1: 5G coverage in EU27, Q2 2020 [Source: GSMA Intelligence, 2020]

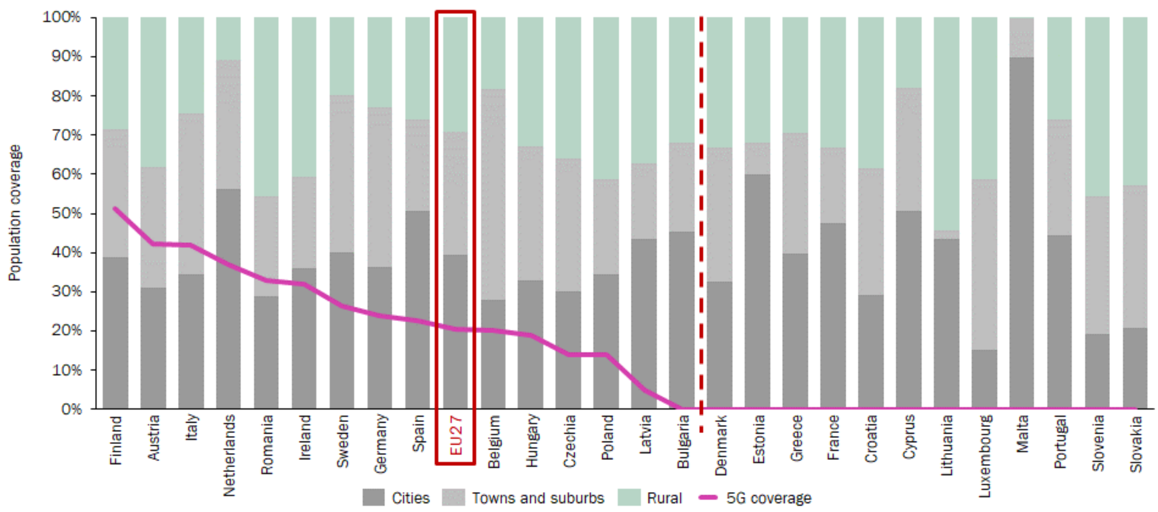
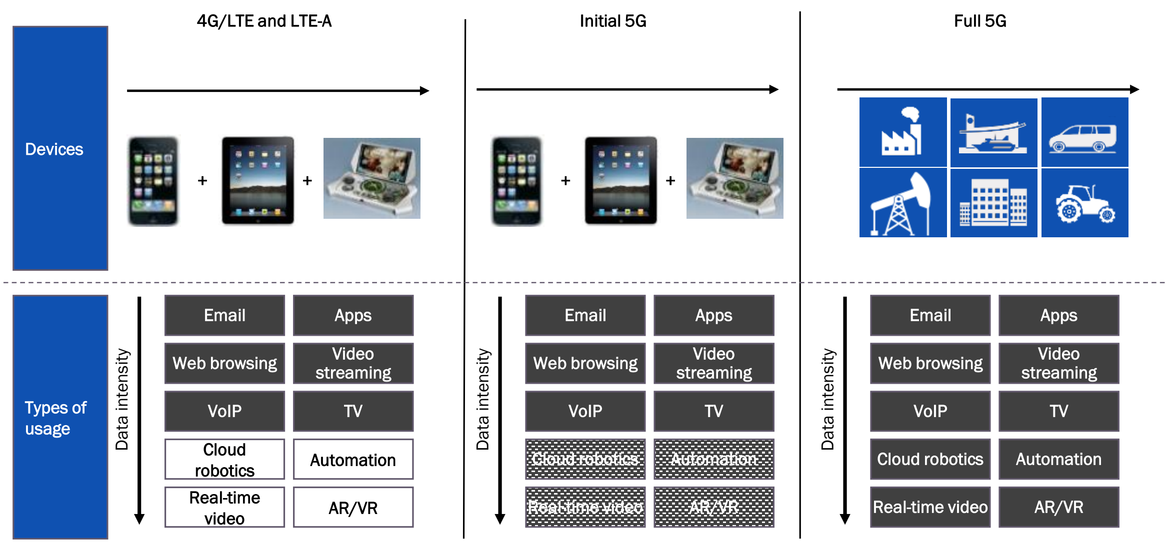


Figure 2.1 above shows the total 5G population coverage in Europe (pink line), overlaid on a classification of the population into three geotypes: urban, suburban and rural. The chart does not indicate the split of 5G coverage across these geotypes (e.g. there may be some 5G coverage of rural areas). For this estimate, we have assumed network deployments generally roll out coverage in more densely populated areas first (i.e. in urban areas, then moving to suburban and then rural areas).

Evolution to standalone, virtualised 5G architectures is now underway, which will increase data intensity in networks with addition of multiple low-latency, ultra-reliable use cases (see Figure 2.2). We note that European MNOs that have confirmed 5G standalone deployments so far in 2020 include Vodafone, Deutsche Telekom, Telenor and Elisa.

Figure 2.2: Mobile traffic and usage evolution with 5G standalone architectures [Source: Ericsson, Qualcomm, Analysys Mason, 2020]



Full 5G capabilities will significantly broaden the uses of 5G networks into multiple verticals with new applications enabled through end-to-end slicing (e.g. collaborative robots, automated machinery, autonomous transport). These applications will be enabled through use of Europe's 5G pioneer bands (700MHz, 3.4–3.8GHz and millimetre-wave (mmWave) spectrum in 26GHz).[2]

Our analysis of the potential benefits of full 5G deployment in Europe has considered published evidence, including benefits indicated by several European 5G trials. Examples of such trials, conducted by Ericsson and Qualcomm, are described in Figure 2.3 below.

Figure 2.3: Examples of European 5G trials and their benefits [Source: Ericsson, Qualcomm, Analysys Mason, 2020]

Benefits indicated by trials	Description of the trial
Productivity, efficiency and safety in the utility sector	• Ericsson, UK water utility provider Northumbria Water and UK MNO O2 are partnering in trials of 5G-augmented reality (AR) technology to remotely inspect assets and enable remote guidance of on-the-ground teams through relaying real-time data and instructions • The trial also demonstrates use of 5G AR technology to provide 3G representation of buried assets, helping utility teams manage hazards and risks in real time[3]
Safer and efficient driving via network-based and direct cellular vehicle to everything (C-V2X)	• Qualcomm and Ericsson, together with Audi, have tested and demonstrated use cases of C-V2X, including vehicle-to-vehicle and vehicle-to-infrastructure direct communication operating in the 5.9GHz ITS spectrum and vehicle-to-network services leveraging 5G (e.g. network slicing and geo-casting)[4] • Trials have included communication across trans-European borders (France, Luxembourg and Germany)
Improved maintenance, production and logistics using industrial 5G	• Ericsson's 5G Port of the Future project pilots 5G virtual reality (VR), AR and artificial intelligence (AI) to improve port operations and efficiency and lower environmental impact • 5G technology has been used for real-time information exchange leading to reduction in movements during cargo handling, resulting in lower fuel consumption and associated CO_2 emissions[5] • Qualcomm is deploying standalone 5G networks in industrial environments in Germany, using the 3.7–3.8GHz band[6]
Enhanced Internet of Things	• The data capacity, speed and low latency that 5G technology delivers will benefit smart city infrastructure in Europe, enabling better data

2 These are fully defined in the 5GAP

3 See https://www.ericsson.com/en/news/3/2020/ericsson-and-o2-partner-with-northumbrian-water-to-harness-the-power-of-5g

4 See https://www.qualcomm.com/news/releases/2018/07/04/convex-consortium-hosts-europes-first-live-c-v2x-direct-communication

5 See https://www.ericsson.com/en/blog/2020/7/5g-port-of-the-future-jul-14-20202

6 For example, 5G manufacturing trials have been conducted by Qualcomm in partnership with Siemens (https://www.qualcomm.com/news/releases/2019/11/26/qualcomm-technologies-and-siemens-set-first-5g-private-standalone-network) and Bosch (https://www.qualcomm.com/news/releases/2019/11/25/qualcomm-technologies-bosch-rexroth-showcase-time-synchronized-industrial)

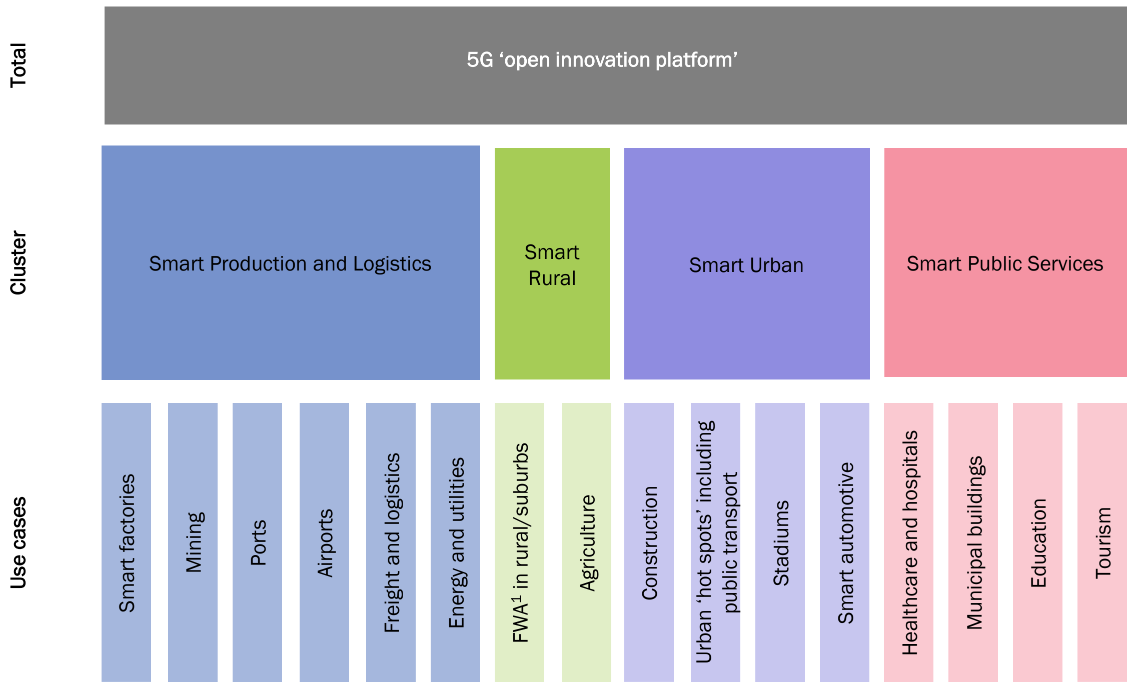
Benefits indicated by trials	Description of the trial
(IoT) in a smart city environment	analytics, more efficient public transport operation and new forms of mobile, on-demand services • Together with edge processing solutions, infrastructure in urban environments can be made safer, more efficient and more innovative[7]

2.2 Framework for cost–benefit analysis in this study

A key part of the study has been to develop a view of 5G as a flexible 'open innovation platform' supporting cross-sector use cases and environments (see Figure 2.4). We have grouped similar 5G use cases into the following 'clusters':

- Smart Production and Logistics
- Smart Rural
- Smart Urban
- Smart Public Services.

Figure 2.4: Overview of 5G open innovation landscape considered in the study [Source: Analysys Mason, 2020]



[1] Fixed-wireless access

[7] See https://www.qualcomm.com/products/smart-cities. See also https://www.vodafone.com/content/dam/vodcom/files/public-policy/gigabit-society-5g-04042017.pdf

The basis of our modelling approach is that full 5G networks can support a wide range of possible innovations in different market and industrial sectors, which collectively can be considered as an overall 'open innovation platform'. The study considers the social, environmental and economic benefits of these use cases, with quantified estimates of economic benefits for each cluster, based on a selection of the use cases within each.

Aggregating similar use cases and network environments into clusters helps to align our conclusions with different European policy themes and provide results which can be more easily interpreted. The individual use cases form the foundations of the cost–benefit analysis, and provide structure for the various input assumptions and data sources.

Summaries of the use cases considered in the four clusters and the associated benefits of these use cases are provided in Annex B.

2.3 Summary of modelling approach

The model we have built estimates both the network costs and the economic benefits for many of the use cases in each cluster. The calculation flows, at a high level, are summarised in Figure 2.5 and Figure 2.6 below.

Figure 2.5: Calculation of the cost of providing the new use cases [Source: Analysys Mason, 2020]

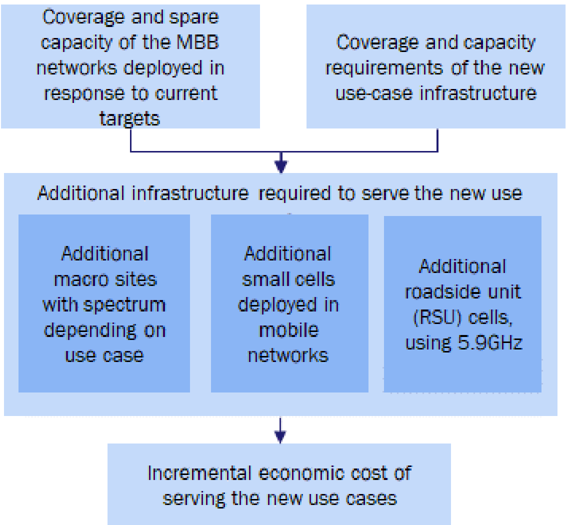
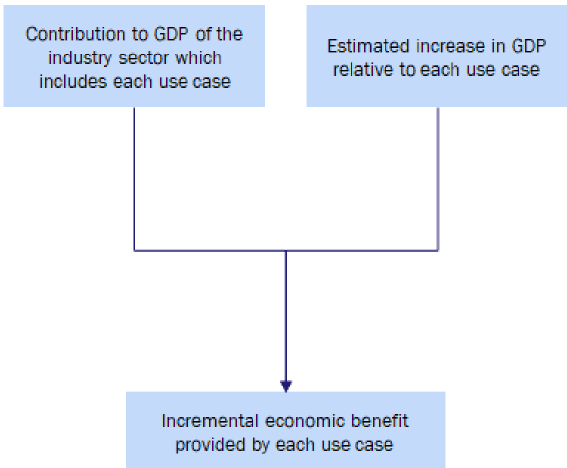


Figure 2.6: Calculation of the benefits of new use cases [Source: Analysys Mason, 2020]



The additional costs, and associated benefits from using 5G to deliver the new use cases are calculated with reference to the 5G networks assumed to be deployed in different European markets as at 2025. Costs and benefits considered in the study are incremental to these current deployments (i.e. the costs and benefits associated with initial 5G deployment for consumer use are excluded from our analysis). The characteristics of 5G eMBB networks in 2025 assumed in the base case are summarised in Figure 2.7 below.

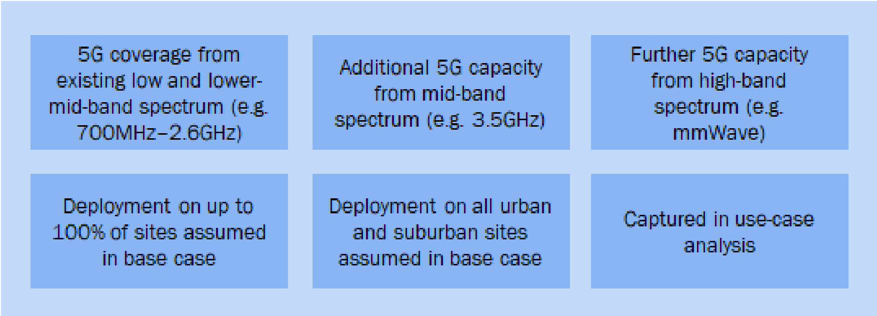


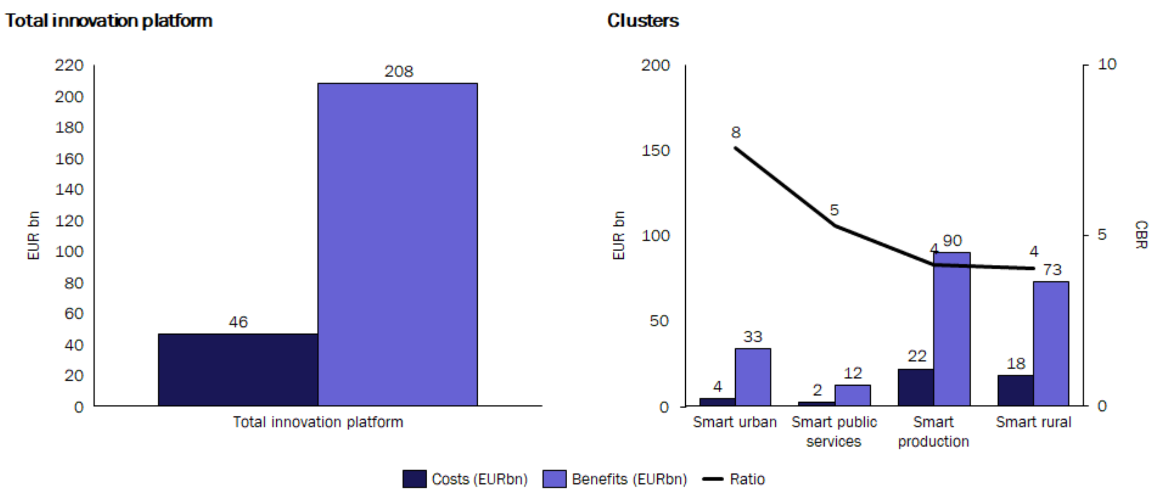
Figure 2.7: Characteristics of 5G eMBB networks in 2025 assumed in the base case [Source: Analysys Mason, 2020]

2.4 Key results

Our modelling indicates that, as a total 'open innovation platform', 5G networks in Europe can deliver c.EUR210 billion in benefits at a cost of c.EUR46 billion (which equates to a cost–benefit ratio (CBR) of 4.5 benefit to cost). The Smart Production and Smart Rural clusters have the largest net benefit (i.e. benefit minus cost), of c.EUR70 billion and c.EUR55 billion respectively, although their CBRs are lower than those of the Smart Urban and Smart Public Services clusters.

Modelling results for the total open innovation platform and individual clusters, aggregated to a European level, are shown in Figure 2.8 below.

Figure 2.8: Total open innovation platform and clusters: 5G upgrade cost, benefit and CBR, Europe [Source: Analysys Mason, 2020][8]



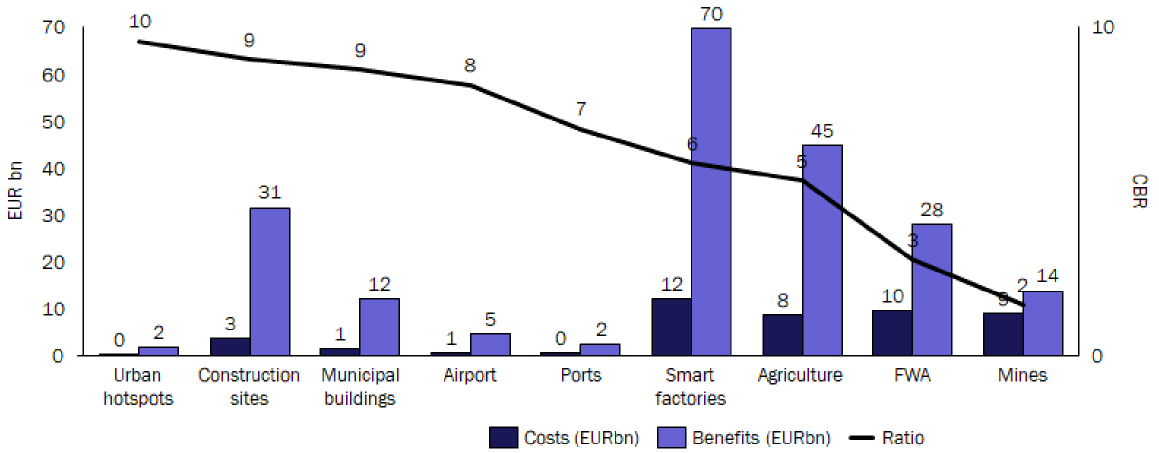
The benefits and costs shown in Figure 2.8 are incremental to the benefits and costs associated with the initial 5G eMBB network investments in Europe – i.e. the benefits and costs shown here are for the expansion of 5G networks to 'full 5G' capability in accordance with our open innovation platform concept, and excludes 5G eMBB consumer benefit.

At the use case level, the largest economic benefits in terms of European GDP impact are from the smart factories, agriculture and FWA (suburban and rural areas) use cases. Results for individual

[8] Results are based on 5G networks assumed to be deployed in European markets in 2025

use cases, aggregated to a European level, are shown in Figure 2.9 below. We have assumed limited synergies between the coverage needs (and thus costs) of different use cases due to localised demand, and have not included any common cost from the MBB network (since we assume that MNOs will make 5G MBB available in any event, due to competitive pressure).

Figure 2.9: Use cases: 5G upgrade cost, benefit and CBR, Europe[9, 10] [Source: Analysys Mason, 2020]



As mentioned previously, the costs and benefits shown in Figure 2.9 above are incremental to the costs and benefits associated with initial 5G deployment and also from any pre-5G mobile deployments (e.g. using 4G technology). Hence, total mobile benefits are likely to be significantly larger than that shown above up to 2025, when also considering consumer MBB services plus other 4G/5G connectivity up to 2025. For example, Analysys Mason modelling for the 5GAA[11] suggests c.EUR3–4 billion of European benefit from C-V2X (i.e. smart automotive) by 2025, rising to c.EUR20 billion by 2030. This benefit is not captured in the charts above.

2.4.1 Commercial investment versus public funding

Many of the use cases we have considered as part of our full 5G assessment are expected to be deployed commercially (i.e. by MNOs, independently of any EU/government targets). In some environments and for some types of deployment where the business case is challenging, use cases are more likely to require public funding. Use cases and their potential public funding requirements are shown in Figure 2.10 below.

9 There are several use cases not shown here that our study has considered, and we have captured in our network costs, but have not modelled a GDP benefit for. We have considered the benefits of 5G to these use cases qualitatively in terms of the potential environmental and social benefits (these include healthcare and hospitals, smart automotive and stadiums). We note that consumer benefit will be generated from these use cases, which we have not modelled, but which several other published studies refer to.

10 FWA is assumed to serve 5–20% of the broadband market outside of areas with fibre to the premises (FTTP) in each country (guided by current propensity to use FWA services).

11 https://5gaa.org/wp-content/uploads/2018/06/2.-Presentation-on-cellular-V2X-socio-economic-benefit-study-08022018.pdf

Cluster	Use case	Requires public funding
Smart Production and Logistics	Smart factories	No
	Mining	No
	Ports	No
	Airports	No
	Freight and logistics	No
	Energy and utilities	No
Smart Rural	FWA	Yes[12]
	Agriculture	Partly[13]
Smart Urban	Construction	No
	Urban hotspots including public transport	Partly[14]
	Stadiums	No
	Smart automotive	Yes
Smart Public Services	Healthcare and hospitals	Yes
	Municipal buildings	Yes
	Education	Yes
	Tourism	Yes

Figure 2.10: 5G use case and whether public funding is required [Source: Analysys Mason, 2020]

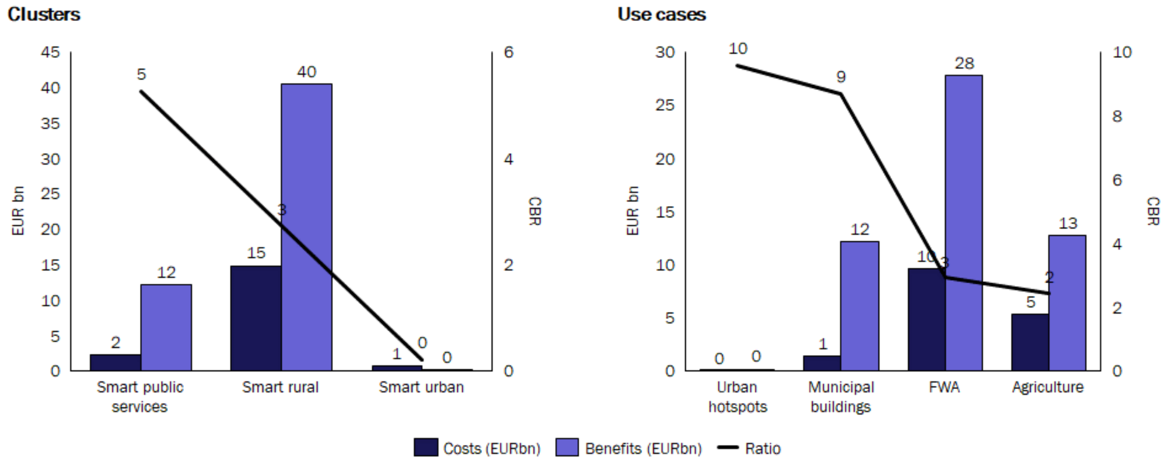
For the use cases where we identify public subsidy will be needed, we estimate that over EUR50 billion of benefit can be delivered for less than EUR20 billion of funding. The costs and benefits (aggregated to a European level) including only those use cases likely to require public funding are shown in Figure 2.11 below.

12 Commercially deployed FWA is assumed as part of initial 5G deployment, but in the 5G FWA use case here we specifically consider additional targeted investment (primarily non-commercial FWA deployments in suburban or remote areas).

13 We assume that the agricultural use case would be delivered commercially if the agricultural environment is within the coverage area of our modelled MBB networks. However, we assume that public subsidy would be required for agricultural environments outside the coverage area of our modelled MBB networks.

14 The urban hotspots use case is assumed to include provision of connectivity for public transport in urban areas (e.g. for provision of real-time passenger and other travel/tourist information). The public-transport portion of the cost associated with this use case (estimated to be around 10%) would require public funding.

Figure 2.11: Clusters and use cases, including only those use cases likely to require public funding: 5G upgrade cost, benefit and CBR, Europe [Source: Analysys Mason, 2020]



Use cases requiring public funding for which we have not modelled an economic benefit as part of this study (e.g. healthcare and hospitals and smart automotive) are not included in the right-hand chart in Figure 2.11. However, government funding for 5G infrastructure to support healthcare and hospitals, and autonomous vehicles, will be highly beneficial and should form part of any European 5G policies, based on previous studies.

2.4.2 Conclusions on future European 5G policies

Realising economic benefit

In terms of GDP benefit, our modelling suggests European 5G policy should focus on:

- accelerating the availability and uptake of 5G infrastructure for Smart Production and Logistics
- enabling 5G coverage to address the Smart Rural cluster.

Our policy recommendations are listed in Figure 2.12 below (by cluster and in order of priority):

Figure 2.12: Recommendations on European 5G policies [Source: Analysys Mason, 2020]

Priority order	Recommended full 5G policies in Europe
1. Smart Production and Logistics policies	• Put the appropriate policies in place to ensure large industrial players can bring 5G solutions (private or public) into production and logistics as part of digital transformation programmes • Make funding available to encourage industrial companies and MNOs to invest in full 5G trials and deployment across multiple verticals, including extensive use of virtual slicing and edge computing
2. Smart Rural policies	• Make 5G rural coverage deployment feasible for MNOs through public subsidies to make mobile networks suitable for 5G rural coverage o this includes partnerships between governments and the mobile industry to deliver consistent 5G mobile

	○ coverage across rural locations (e.g. via shared deployment models) ○ this could connect remote premises, rural industry and rural transport routes • Include 5G FWA as a technology option within future targets and funding for superfast/ultrafast broadband provision
3. Smart Urban policies, including urban transport corridors	• Bring 5G into new and enhanced urban solutions including edge computing and robotics through appropriate vertical policies (e.g. construction, transport, automotive) • Trial 5G-based AI solutions in European cities (e.g. 5G infrastructure for transport, logistics, smart estates, stadiums) • Bring mmWave bands such as 26GHz into use by 2025 (could be linked to specific clusters such as Smart Urban)
4. Smart Public Services policies	• Ensure public authorities can make specific 5G investments (e.g. in next-generation connectivity plans and funding) for facilities management, provision of public services, maintenance of public spaces • Continue to promote trials and test-beds of advanced 5G capabilities (including high-quality indoor coverage) in the healthcare sector, and encourage public authorities to make use of 5G in municipal buildings to aid education, recreation, tourism and business

In addition to the above policy recommendations, it will be essential for accelerated roll-out of 5G to continue over the coming years up to 2025, in line with the existing 5GAP. Completing the remaining spectrum awards across Europe in all 5G pioneer bands (700MHz, 3.4–3.8GHz and 26GHz) will be important to accelerate 5G deployment. There should also be a focus on reducing any barriers to deployment (e.g. reducing deployment costs to accelerate speed of roll-out, as per the recent European Commission recommendation on a common toolbox for reducing the cost of high-capacity network deployment[15]).

To date, our calculation is that:

- In the 3.4–3.8GHz band, 15 countries out of the 30 modelled have awarded 5G spectrum (with c.40% of the available bandwidth in the 3.4–3.8GHz band awarded on average).
- In the 700MHz band, this drops to 12 out of 30 countries modelled (with c.40% of available bandwidth awarded on average).
- In the 26GHz band, only three countries (Italy, Finland and the UK) have awarded spectrum suitable for 5G to date (c.5% of the pioneer bandwidth has been awarded on average).[16]

15 https://ec.europa.eu/digital-single-market/en/news/commission-recommendation-common-union-toolbox-reducing-cost-deploying-very-high-capacity

16 Figures are straight averages across the 30 European countries modelled of the amount of spectrum assigned (and suitable for 5G) in each pioneer band: 700MHz (2x30MHz), 3.4–3.8GHz and 24.25–27.5GHz. Local/regional 5G assignments have been included, but temporary/trial assignments have been excluded.

Realising environmental and social benefits

From an environmental and social benefits perspective, high priorities for European policy are improving 5G coverage in the Smart Rural cluster, and enabling 5G use in the smart factories, and in the freight and logistics use cases. A summary of the environmental and social benefits associated with 5G connectivity for the clusters are summarised, by use case, in Figure 2.13 below. Use cases with the highest benefit have been shaded green (with medium benefit shaded orange, and lower benefits shaded yellow). The highest-priority use cases (i.e. factories, freight and logistics, and use cases in the Smart Rural cluster) have been indicated with a red border.

Figure 2.13: Summary of environmental and social benefits by use case[17] [Source: Analysys Mason, 2020]

Cluster	Use case	Environmental benefit from 5G connectivity	Social benefit from 5G connectivity
Smart Production and Logistics	Ports	Logistics efficiency leading to carbon emission reduction	Increased security, safety and technology-skilled workforces
	Airports	Reduced congestion	Increased security, safety Less time waiting in airports/ enhanced passenger experience
	Mining	Real-time monitoring in mines e.g. air quality, risk of hazards	Increased security, safety, technology-skilled workforces
	Smart factories	Better use of time and materials, leading to reduced energy use Industrial process and equipment monitoring enabling improved equipment lifetimes	Increased security, technology-skilled workforces
	Freight and logistics	Facilitate 'just-in-time' supply chains, efficient transport of goods	Increased safety/reduction or prevention of accidents
	Energy and utilities	Remote monitoring/remote inspection enabling better control of energy use	Encourage good energy use through real-time awareness of energy being used
Smart Rural	5G FWA	Reduced journeys (e.g. working remotely plus connectivity in rural transport corridors)	Social inclusion/reducing the digital divide Slow or reverse rural population declines Support for rural businesses to operate digitally

17 Green = highest benefit, orange = medium benefit; yellow = lower benefit. The highest priority use cases are shown with a red border

Cluster	Use case	Environmental benefit from 5G connectivity	Social benefit from 5G connectivity
	Agriculture	Increased efficiency/lower carbon farming	Sustained rural industries Ability to market products beyond local area
Smart Urban	Construction	Fuel efficiency/reduced carbon emissions	Safety-related benefits, e.g. reduction in accidents Reduced driving times/ wellbeing
	Urban hotspots including public transport	Improved public transport operations Smart buildings/ support for green building initiatives	Improved city living experience Better access to information and media whilst travelling
	Stadiums	Support for green initiatives in stadiums	Better enjoyment/ experience
	Smart automotive	Better energy use/less waste Support for green construction policies, e.g. remote management of machines	Increased safety of building sites
Smart Public Services	Healthcare and hospitals	Reduced journeys (e.g. ambulances to hospitals or patient journeys to GP surgeries)	Highly reliable remote consultation and triage
	Municipal buildings	Fewer journeys needed to monitor or resolve social problems) Better energy use/less waste	Collaboration or interaction (e.g. 5G connectivity for social or business hubs)
	Education	Support for green school and university initiatives, e.g. energy-saving or other environmental projects	Increased availability and access to education/remote learning in schools and universities Remote access to experts
	Tourism	Conservation benefits, e.g. enabling tourists to better understand environmental challenges via VR/AR experience	Virtual walk-throughs of tourist sites/improved quality of experience Educational benefits

Annex A Individual country results

This annex provides the results of the costs and economic benefits modelling associated with the different clusters on an individual country basis.

While we can account for country-specific differences using high-level modelling inputs (GDP per capita, sectoral GDP, sites, traffic, number of use-case location etc.), specific dynamics in individual countries (e.g. level of digitisation in certain sectors of the economy) have not been captured. Modelling inputs have not been available for all countries (in which case European averages have been used). Individual country results should therefore be treated with caution

Results are presented by country (in order of CBR) for each cluster in the following sub-sections.

- Section A.1 – Smart Production and Logistics
- Section A.2 – Smart Rural
- Section A.3 – Smart Urban
- Section A.4 – Smart Public Services.

A.1 Smart Production and Logistics cluster

The four use cases that have been modelled in the Smart Production and Logistics cluster are:

- mining
- smart factories
- ports
- airports.

Results for this cluster are shown in Figure A.1 below.

Figure A.1: Costs and benefits by country, Smart Production and Logistics cluster [Source: Analysys Mason, 2020]

Country	Costs (EUR million)	Benefits (EUR million)	CBR
Ireland	260	3,130	12.0
Switzerland	437	4,887	11.2
Germany	3,519	25,608	7.3
Denmark	256	1,782	7.0
Belgium	287	1,798	6.3
Austria	441	2,418	5.5
Netherlands	513	2,631	5.1
France	1,403	7,012	5.0
Finland	519	2,552	4.9
Sweden	529	2,516	4.8

Country	Costs (EUR million)	Benefits (EUR million)	CBR
UK	1,671	6,609	4.0
Poland	1,926	7,299	3.8
Czechia	707	2,284	3.2
Luxembourg	23	68	3.0
Cyprus	20	57	2.9
Bulgaria	473	1,363	2.9
Hungary	428	1,157	2.7
Romania	996	2,531	2.5
Slovenia	126	309	2.4
Spain	1,811	4,357	2.4
Italy	2,405	5,489	2.3
Greece	408	847	2.1
Slovakia	243	455	1.9
Malta	26	49	1.8
Lithuania	191	305	1.6
Norway	708	1,098	1.6
Estonia	141	188	1.3
Croatia	228	285	1.2
Portugal	832	840	1.0
Latvia	192	171	0.9

The cost of coverage for mines and smart factories is much higher than that for ports and airports. Smart factories are nearly always the largest component of the total benefit in this cluster (although in a few cases the mining sector is bigger). Countries with a high CBR in this cluster therefore generally have a large manufacturing sectoral GDP per smart factory (as in the case of Ireland).

A.2 Smart Rural cluster

The Smart Rural cluster consists of two use cases: agriculture and FWA – both have been modelled.

The top results for the Smart Rural cluster are driven by low levels of FTTP (meaning more FWA take-up) and high GDP per unit area of farmland. Results for this cluster are shown in Figure A.2 below.

Figure A.2: Costs and benefits by country, Smart Rural cluster [Source: Analysys Mason, 2020]

Country	Costs (EUR million)	Benefits (EUR million)	CBR
Netherlands	155	3,364	21.7
Switzerland	152	2,208	14.5
Latvia	27	351	13.2
Cyprus	15	190	12.3
Norway	148	1,384	9.3
Malta	7	52	7.9

Country	Costs (EUR million)	Benefits (EUR million)	CBR
Denmark	198	1,505	7.6
Slovenia	30	227	7.5
Belgium	87	572	6.6
Estonia	50	308	6.1
Germany	1,451	8,711	6.0
Czechia	403	2,270	5.6
Hungary	303	1,626	5.4
Ireland	178	919	5.2
Portugal	180	870	4.8
Spain	1,347	6,181	4.6
Austria	1,319	5,990	4.5
France	1,786	7,920	4.4
Croatia	142	605	4.3
Romania	639	2,713	4.2
Greece	400	1,514	3.8
Luxembourg	9	35	3.7
UK	920	3,197	3.5
Bulgaria	277	961	3.5
Slovakia	232	747	3.2
Lithuania	124	397	3.2
Sweden	523	1,623	3.1
Finland	1,248	3,651	2.9
Poland	1,999	5,563	2.8
Italy	3,647	6,922	1.9

The cost is calculated separately per use case (agriculture and FWA) for the provision of coverage to:

- Locations within the existing MBB network (traffic is served over the existing MBB network, and thus depends on the level of spare capacity).
- Locations outside the existing MBB network (new sites are built, and the cost is purely driven by area to be covered). In the case of FWA, the cost is also driven by the level of existing FTTP deployment.

The total CBR of the cluster is thus driven by various factors. Countries with a high CBR (e.g. Switzerland) benefit from a relatively low level of FTTP coverage and relatively high level of spare capacity on the existing MBB network, meaning a large contribution from the FWA use case. Other countries, with a high agricultural GDP per unit area farmed (e.g. the Netherlands), have a large contribution from the agricultural use case.

A.3 Smart Urban cluster

The use cases that have been included in the Smart Urban cluster are:

- construction
- urban hotspots
- stadiums
- smart automotive.

In this cluster, construction sites form the largest cost and benefits component: the cost of coverage is around four times higher than that for smart automotive. Results for this cluster are shown in Figure A.3 below.

Figure A.3: Costs and benefits by country, Smart Urban cluster [Source: Analysys Mason, 2020]

Country	Costs (EUR million)	Benefits (EUR million)	CBR
Switzerland	74	2,751	37.4
UK	303	4,804	15.9
Denmark	80	978	12.2
Austria	133	1,594	12.0
Germany	668	7,821	11.7
Belgium	53	608	11.4
Netherlands	105	1,108	10.6
Norway	90	868	9.6
France	387	2,833	7.3
Cyprus	12	82	6.9
Latvia	22	152	6.9
Romania	208	1,400	6.7
Estonia	12	79	6.6
Luxembourg	31	180	5.7
Poland	305	1,507	4.9
Spain	340	1,584	4.7
Ireland	48	214	4.5
Finland	166	738	4.4
Portugal	72	298	4.1
Sweden	294	1,126	3.8
Hungary	70	254	3.6
Czechia	85	292	3.4
Malta	1	2	3.3
Slovenia	27	86	3.2
Greece	31	87	2.8
Croatia	65	178	2.7
Lithuania	77	187	2.4
Italy	409	951	2.3

Country	Costs (EUR million)	Benefits (EUR million)	CBR
Bulgaria	132	284	2.1
Slovakia	89	114	1.3

The aggregate benefit within the Smart Urban cluster for a given country is overwhelmingly derived from construction sites (with no economic benefit modelled for smart automotive or stadiums, and the benefit from urban hotspots being much lower). Accordingly, the construction use case generally has the biggest impact on the CBR of this cluster.

Countries with a high CBR tend to have a large construction sectoral GDP (per construction site), and spare capacity on the MBB network (used to provide coverage for construction sites).

A.4 Smart Public Services cluster

The use cases that have been included in the Smart Public Services cluster are:

- healthcare and hospitals
- municipal buildings
- education
- tourism.

Countries which are expected to benefit most from Smart Public Sector initiatives are those with a relatively low number of municipal buildings to cover. Results for this cluster are shown in Figure A.4 below.

Figure A.4: Costs and benefits by country, Smart Public Services cluster [Source: Analysys Mason, 2020]

Country	Costs (EUR million)	Benefits (EUR million)	CBR
Sweden	8	436	54.0
Netherlands	20	647	32.1
Belgium	18	345	19.5
Norway	23	305	13.2
Switzerland	40	490	12.4
Malta	1	16	12.3
Luxembourg	2	21	10.9
Finland	19	187	10.0
UK	185	1,531	8.3
Slovenia	4	32	7.8
Germany	315	2,325	7.4
Denmark	37	267	7.3
Austria	41	263	6.5
Italy	156	891	5.7
Estonia	4	23	5.3
Latvia	5	26	5.1
Spain	188	852	4.5

Country	Costs (EUR million)	Benefits (EUR million)	CBR
Poland	91	388	4.3
Croatia	10	36	3.4
France	598	1,965	3.3
Portugal	49	149	3.0
Ireland	46	138	3.0
Romania	68	187	2.8
Lithuania	12	32	2.7
Cyprus	12	30	2.5
Hungary	47	106	2.2
Czechia	88	155	1.8
Greece	90	140	1.6
Slovakia	42	62	1.5
Bulgaria	81	50	0.6

The cost of coverage for municipal buildings is typically around 50% higher than that for hospitals (though nine times as many small cells are required per hospital than per municipal building, there are nearly fourteen times as many municipal buildings). No economic benefit is modelled for the healthcare and hospitals use case. For municipal buildings, the size of the benefit corresponds to public administration sectoral GDP per municipal building.

Countries with a higher CBR in this cluster (Sweden, the Netherlands, Belgium) are those which have a small number of municipal buildings (per capita).

Annex B Use cases considered in the four clusters and their associated benefits

Summaries of the use cases considered in the four clusters and their associated benefits are provided in Figure B.1–Figure B.4 below.

Smart Production and Logistics

The Smart Production and Logistics cluster is expected to deliver a wide range of social, environmental and economic benefits, with 5G enhancing or enabling new uses. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure B.1 below.

Figure B.1: Summary of use cases considered in the Smart Production and Logistics cluster and their associated benefits[18] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Smart factories	Machinery monitoring for predictive maintenance and remote-control: reduced downtime Real-time supply chain visibility X-reality guided procedures and repairs Ultra-high definition (UHD) surveillance	Increased security and safety Increased technologically skilled workforce	Real-time monitoring of processes to reduce energy and materials consumption Reduced equipment replacement/ maximised equipment lifetimes	GDP contribution uplift due to increased productivity
Mining	Drone-based video inspections Autonomous vehicles Predictive maintenance UHD surveillance	Increased security and safety Increased technologically skilled workforce	Better air quality monitoring/ reduced risk of hazards (e.g. through real-time monitoring within mines)	GDP contribution uplift due to increased productivity

18 We do not consider jobs created/displaced as part of our assessment

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Ports	Real-time inventory and asset tracking UHD surveillance Robotic control of machinery AR guided repairs	Increased security and safety Increased technologically skilled workforce	Reduced carbon emissions through greater logistic efficiency and equipment efficiencies	GDP contribution uplift due to increased productivity
Airports	Autonomous airside vehicles and collision avoidance AR guided repairs and maintenance Edge computing and AI for passenger ID and security Augmented shopping experience	Increased security and safety Less time spent waiting in airports	Reduced congestion and reduced emissions (e.g. autonomous airside vehicles)	GDP contribution uplift due to increased productivity
Freight and logistics	Non-line-of-sight accident sensing Autonomous freight vehicles Sensor data sharing for smart fleet management	Increased safety	Efficient just-in-time supply chains, reduces unnecessary journeys and transportation of goods	Improved work processes and productivity (not modelled) Possibility of new business models (not modelled)
Energy and utilities	Smart load balancing and detection of peaks/surges Smart fault sensors Management of sending energy back to the grid	Encouraging good energy behaviour within homes and businesses (including for use of electric vehicles)	Better energy consumption management by more closely matching supply and demand	Improved work processes (not modelled)

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
	Predictive maintenance of assets (e.g. wind turbines) AR-guided maintenance/repairs		Lower greenhouse gas (GHG) emissions (e.g. due to increased use of remote monitoring)	

Smart Rural

5G-based connectivity is expected to enable the Smart Rural cluster to deliver benefits to people and businesses, helping to sustain rural living and aid working remotely. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure B.2 below.

Figure B.2: Summary of use cases considered in the Smart Rural cluster and their associated benefits[19] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits
FWA in suburban and rural areas	High-speed broadband connectivity for consumers and business in areas not reached by full-fibre networks Could also support implementation of other 5G use cases, such as remote monitoring/remote healthcare	Increased social inclusion; reduced digital divide Could slow or reverse decline in populations living in rural areas/ contribute to maintaining rural communities. Ability for local businesses to access wider markets for their products via e-commerce, supporting rural sustainability Ability to work from home/create a better work–life balance Alternative to fixed broadband (FBB) and/or resilience (e.g. use of a mobile device when FBB is not available)	Reduced journeys (e.g. from being able to work remotely)
Agriculture	Massive sensor network for crops (pest detection and moisture levels) and livestock Untethered surveillance drones Autonomous machinery	Rural sustainability (support for local industries including fishing, tourism and farming in remote areas) Ability of rural producers to market products beyond local area (e.g. using e-commerce platforms)	Increased efficiency (e.g. lower carbon farming) Potential for reduced waste/reducing unnecessary use of products (e.g. fertiliser) Reduction in land requirements for livestock

Smart Urban

5G in the Smart Urban cluster, together with edge computing, is expected to deliver benefits across multiple use cases, by enhancing existing use cases and creating new uses. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure B.3 below.

Figure B.3: Summary of use cases considered in the Smart Urban cluster and their associated benefits[20] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Construction	UHD surveillance Remote sensor monitoring of equipment, machines and materials Autonomous vehicles and equipment Collaborative robots	Increased safety and security of building sites	Better energy use/less waste Support for green construction practices (e.g. remote management of machines)	GDP contribution uplift due to increased productivity
Urban 'hot spots' (including public transport in urban centres)	Always-on connectivity for communications and e-commerce – enabling more people to be connected to real-time services (including video) Optimised public transport networks (e.g. improved route planning, real-time information,	Wellbeing benefits for those living in cities: better access to entertainment/ e-commerce while travelling Lower journey times on public transport and better information	Reduced emissions from optimised public transport networks Smart buildings/green building initiatives More efficient public transport journeys	GDP contribution uplift due to increased productivity

20 We do not consider jobs created/displaced as part of our assessment

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
	passenger infotainment)			
Stadiums	New immersive experiences (e.g. multi-view AR/VR) Social video sharing UHD video surveillance Real-time smart parking	Enjoyment/ experience (e.g. ability to replay live video, interact with the event) Additional viewing content (e.g. behind the scenes)	Support for green initiatives in stadiums	New business models/ financial benefits for the sports club (not modelled)
Smart automotive	Real-time optimised routing and advanced traffic management Increased real-time situational awareness for driver Non-line-of-sight accident sensing	Safety-related benefits (e.g. reduction in accidents) Optimised driving patterns and reduced journey time create a wellbeing benefit	Increased fuel efficiency and reduced emissions (e.g. due to access to real-time map updates, real-time parking data, making journeys shorter)	New business models (not modelled)

Smart Public Services

The Smart Public Services cluster is expected to enable enhancements in communication for a range of public services, plus new capabilities and tools. A summary of the use cases considered in this cluster and their associated benefits is shown in Figure B.4 below.

Figure B.4: Summary of use cases considered in the Smart Public Services cluster and their associated benefits[21] [Source: Analysys Mason, Ericsson, Qualcomm, 2020]

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
Healthcare and hospitals	Remote monitoring of patients/early warning of changes in vital signs Video, medicine and 'tactile internet'[22] Smart objects (e.g. real-time management of medical resources)	High-reliability remote consultation and triage Increase in social inclusion and wellbeing; improved care	Reduced journeys (e.g. ambulances to hospitals or journeys to GP surgeries) More preventative care/less pressure on hospitals and healthcare providers	Reduced expenditure (e.g. time or money) due to preventative healthcare, leading to lower healthcare costs/ increased capacity (not modelled)
Municipal buildings	Highly available and low-latency connections providing capacity to support more users with higher-speed services (including real-time video)	Better energy use/less waste Collaboration/interaction (e.g. social or business hubs)	Possible reduction in journeys (e.g. fewer journeys for monitoring and resolving social problems)	GDP contribution uplift due to increased productivity
Education	Remote/home-based teaching via interactive platforms	Increased availability and access to education, including remote learning in schools and universities	Green school initiatives (e.g. high-speed, low-latency connectivity to support energy saving;	-

21 We do not consider jobs created/displaced as part of our assessment

22 Remote monitoring also requires connectivity at home – we have not modelled the benefit of remote monitoring of patients although we note this could be part of the benefit of 5G FWA provided in suburban/rural areas, as indicated in **Error! Reference source not found.**.

Use case	Features of the use case	Social benefits	Environmental benefits	Economic benefits
	Immersive augmented/virtual-based learning[23] Remote native-language speakers/ additional remote expert education	Remote access to experts	environmental projects in schools or universities)	
Tourism	Enhancement of tourism experiences through VR/AR	Virtual walk-throughs of tourist sites/quality of experience Educational benefits	Conservation benefits (e.g. enabling tourists to better understand environmental challenges via VR/AR)	New business models from immersive tours