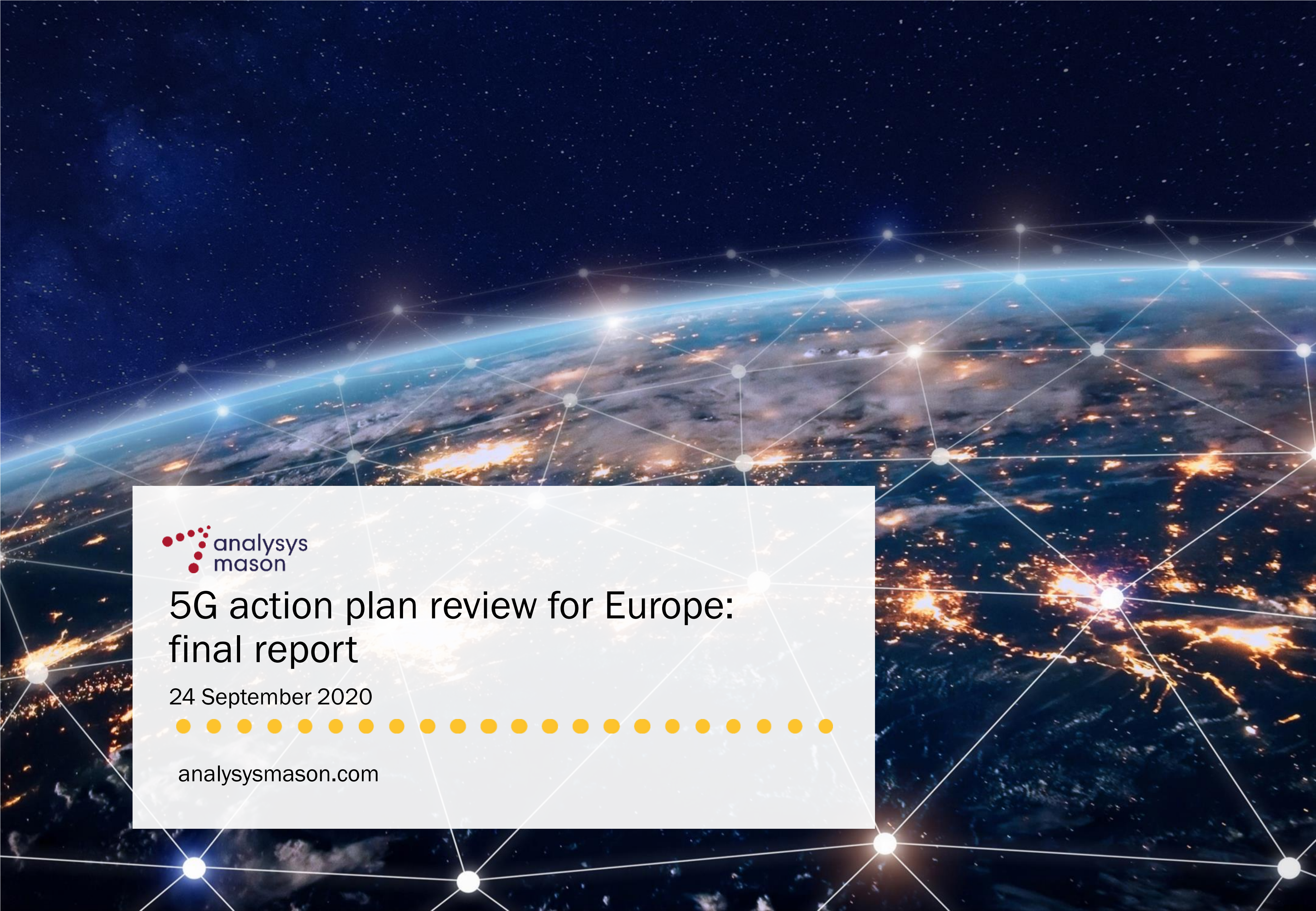

5G action plan review for Europe: final report

24 September 2020

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Contents

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The overall aim of the study is to analyse costs and benefits of 'full 5G' use cases in Europe, to support review and potential updating of the European 5G Action Plan

- Ericsson and Qualcomm commissioned Analysys Mason to conduct a study to assess costs and benefits of new use cases via 5G networks, with the overall goal to provide inputs to review of Europe's 5G Action Plan (5GAP)
- Current European targets for initial 5G deployment are contained in the existing 5GAP:
  – the 5GAP was aimed at launching initial 5G networks in Europe by 2020, and to promote 5G coverage across urban areas, and main transport paths, by 2025
  – several spectrum bands are being made available for 5G in Europe based on the 5GAP, meeting coverage and capacity requirements
  – bands below 1GHz and the 3.5GHz band are being deployed both for 5G coverage, and for capacity. As per the 5GAP, higher bands (e.g. 26GHz) can also enable very high capacity in locations where traffic demand is highest, taking account of the diverse requirements for 5G use cases in different environments
- The aim of this study has been to provide a cost–benefit analysis to inform development of updated European 5G goals (including releasing 5G's full potential to aid 5G recovery post 2020), and taking account of experience from 5G trials, technology development and deployments since the 5GAP was developed back in 2016

The focus of the study has been on the innovative new use cases and varied environments that 5G is designed to support, in addition to the speed and capacity increases 5G can provide for consumers using enhanced mobile broadband (eMBB) built on existing 4G 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.

The study has referred to existing studies discussing the qualitative benefits of the new 5G use cases. As many of these benefits are yet to be realised on a large scale, much of the assessment of the impact of new use cases is based on limited published evidence to date.

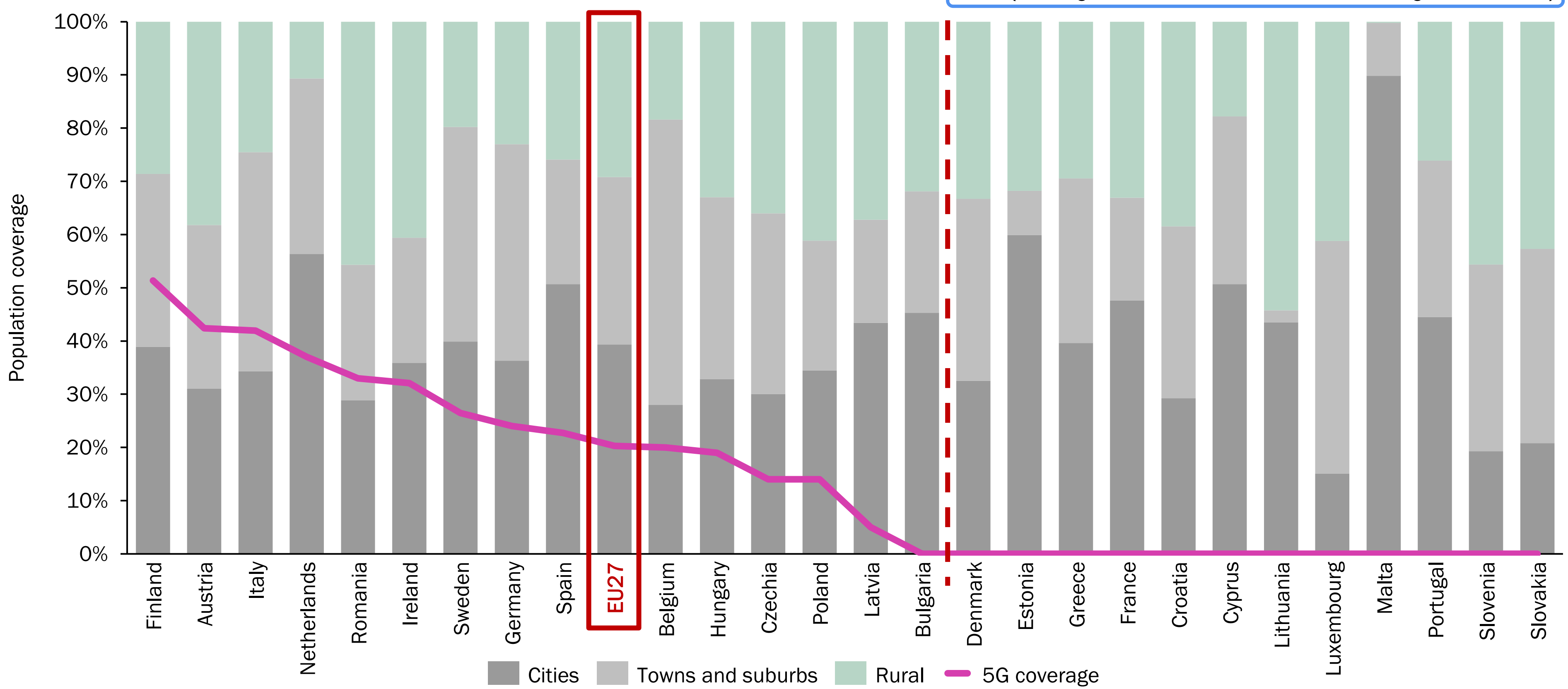
However, the study also aims to bring new insight to the debate around the value of 5G: by providing a detailed and robust cost-benefit analysis of selected new 5G uses cases, to provide further quantitative estimate of the impact of 5G in shaping Europe's digital future.

Source: Analysys Mason

In European countries where 5G has been launched, Finland has the highest population coverage (over 50%) whereas most countries are at 15–40%

5G coverage progress in Europe, Q2 2020, © GSMA Intelligence 2019/20

In countries to the right of the dashed line, 5G commercial networks had not been launched at the time of producing this chart (although some launches are imminent e.g. in Denmark)



The chart above shows total 5G population coverage (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, then moving to suburban and then rural areas).

Source: Analysys Mason, Eurostat, GSMA Intelligence

Evolution to standalone, virtualised 5G architectures is underway, which will increase data intensity in networks with low-latency, ultra-reliable use cases

4G/LTE and LTE-A

Devices

User-friendly smartphones, and the development of the app market, significantly increased consumer data needs – some operators have launched 4G+ services to increase peak and average network speeds

Types of usage (Data intensity ↓)

Email	Apps
Web browsing	Video streaming
VoIP	TV
Cloud robotics	Automation
Real-time video	AR/VR

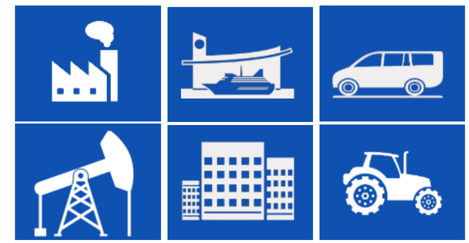
Initial 5G

With initial 5G services focusing on the consumer market, devices are similar to the devices used in 4G+, including smartphones, tables and portable gaming devices – with pre-commercial showcases of ultra-reliable use cases

Data intensity ↓

Email	Apps
Web browsing	Video streaming
VoIP	TV
Cloud robotics	Automation
Real-time video	AR/VR

Full 5G[1]



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) and new spectrum (incl. mmWave)

Data intensity ↓

Email	Apps
Web browsing	Video streaming
VoIP	TV
Cloud robotics	Automation
Real-time video	AR/VR

Note: European operators who have confirmed standalone deployments so far in 2020 include Vodafone, Deutsche Telekom, Telenor and Elisa

[1] Analysys Mason, Ericsson (https://www.ericsson.com/en/blog/2020/4/reducing-mobility-interruption-time-5g-networks) and Qualcomm (https://www.qualcomm.com/invention/5g/cellular-v2x)

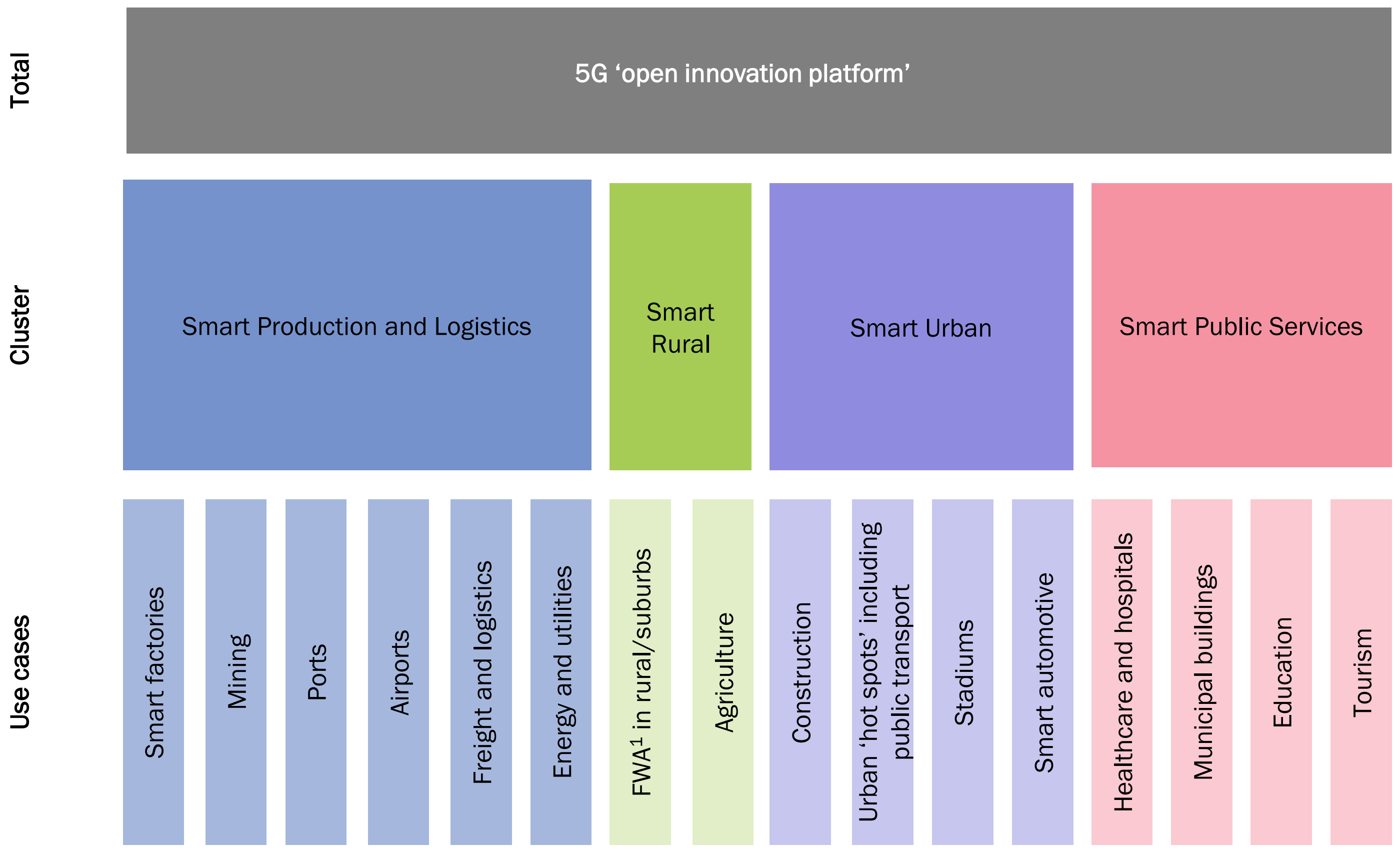
To identify potential benefits from full 5G deployment in Europe, we have considered published evidence including benefits indicated by several European trials

Benefits delivered by 5G trials	Description of the objective of the trial
Productivity, efficiency and safety in the utility sector	▪ Ericsson, UK water utility provider Northumbria Water and UK mobile network operator (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
Safer and efficient driving via network-based and direct 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) ▪ 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 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 ▪ Qualcomm is deploying stand-alone 5G networks in industrial environments in Germany, using the 3.7–3.8GHz band, demonstrating 5G applications in industrial settings
Enhanced IoT in a smart city environment	▪ The data capacity, speed and low latency that 5G technology delivers will benefit smart city infrastructure in Europe, enabling better data 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

Source: Analysys Mason, Ericsson (https://www.ericsson.com/en/news/3/2020/ericsson-and-o2-partner-with-northumbrian-water-to-harness-the-power-of-5g and https://www.ericsson.com/en/blog/2020/7/5g-port-of-the-future-jul-14-20202), Qualcomm (https://www.qualcomm.com/news/releases/2018/07/04/convex-consortium-hosts-europes-first-live-c-v2x-direct-communication and https://www.qualcomm.com/products/smart-cities) and Vodafone (https://www.vodafone.com/content/dam/vodcom/files/public-policy/gigabit-society-5g-04042017.pdf). See also 5G manufacturing trials 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)

5G can be viewed as a flexible ‘open innovation platform’ supporting cross-sector use cases and environments, which we have grouped into ‘clusters’

Overview of the 5G open innovation landscape considered in the study



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’

It is useful to aggregate similar use cases into ‘clusters’ to align with different 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.

The study considers the social, environmental and economic benefits of these use cases, with quantified estimates of economic benefits

[1] Fixed-wireless access

Source: Analysys Mason

The Smart Production and Logistics cluster can deliver a wide range of social, environmental and economic benefits, with 5G enhancing or enabling new uses[1]

Summary of use cases considered in the Smart Production and Logistics cluster and their associated benefits

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/safety; technologically skilled workforce	Real-time monitoring of processes to reduce energy and materials consumption Reduced equipment replacement	GDP contribution uplift due to increased productivity
Mining	Drone-based video inspections Autonomous vehicles Predictive maintenance; UHD surveillance	Increased security; technologically skilled workforce	Better air quality monitoring/ reduced risk of hazards (monitoring within mines)	GDP contribution uplift due to increased productivity
Ports	Real-time inventory and asset tracking UHD surveillance; reliable robotic control of machinery; AR guided repairs	Increased security; technologically skilled workforce	Reduced carbon emissions through greater logistic efficiency	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/safety; less time spent waiting in airports	Reduced congestion	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 here) Possibility of new business models (not modelled here)
Energy and utilities	Smart load balancing and detection of peaks/surges Smart fault sensors Management of sending energy back to the grid Predictive maintenance of assets (e.g. wind turbines) AR-guided maintenance/repairs	Encouraging good energy behaviour	Better energy consumption management by more closely matching supply and demand Lower GHG emissions (e.g. due to remote monitoring)	Improved work processes (not modelled here)

[1] We do not consider jobs created/displaced as part of our assessment

Source: Analysys Mason, Ericsson, Qualcomm

A quantitative estimate of economic benefits and costs is presented later in this section

The Smart Rural cluster benefits from 5G-based connectivity to deliver benefits to people and businesses, helping to sustain rural living and aid working remotely

Summary of use cases considered in the Smart Rural cluster and their associated benefits

Use case	Features of the use case	Social benefits	Environmental benefits	Economic 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)	GDP contribution uplift due to increased productivity for remote workers[1]
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	GDP contribution uplift due to increased productivity[1]

[1] We do not consider jobs created/displaced as part of our assessment

Source: Analysys Mason, Ericsson, Qualcomm

A quantitative estimate of economic benefits and costs is presented later in this section

5G in the Smart Urban cluster together with edge computing is expected to deliver benefits across multiple use cases, where 5G can enhance and create new uses*

Summary of use cases considered in the Smart Urban cluster and their associated benefits

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, passenger infotainment)	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
Stadiums	New immersive experiences (e.g. multi-view AR/VR) Social video sharing UHD video surveillance Real-time smart parking	Enjoyment/experience (ability to replay live video, interact with the event, etc.) 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 here)
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) Optimising driving patterns and reducing journey time creates 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 here)

[1] We do not consider jobs created/displaced as part of our assessment

Source: Analysys Mason, Ericsson, Qualcomm

A quantitative estimate of economic benefits and costs is presented later in this section

The Smart Public Services cluster is expected to enable enhancements in communication for a range of public services, plus new capabilities and tools

Summary of use cases in the Smart Public Services cluster and their associated benefits

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'[1] 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 here)
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[2]
Education	Remote/home-based teaching via interactive platforms Immersive XR-based learning Remote native-language speakers/ additional remote expert education	Increased availability and access to education, including remote learning in schools and universities Remote access to experts	Green school initiatives (e.g. high-speed, low-latency connectivity to support energy saving or environmental projects in schools or universities)	-
Tourism	Enhancement of tourism experiences through virtual reality / augmented reality	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

[1] 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 indicated on slide 10

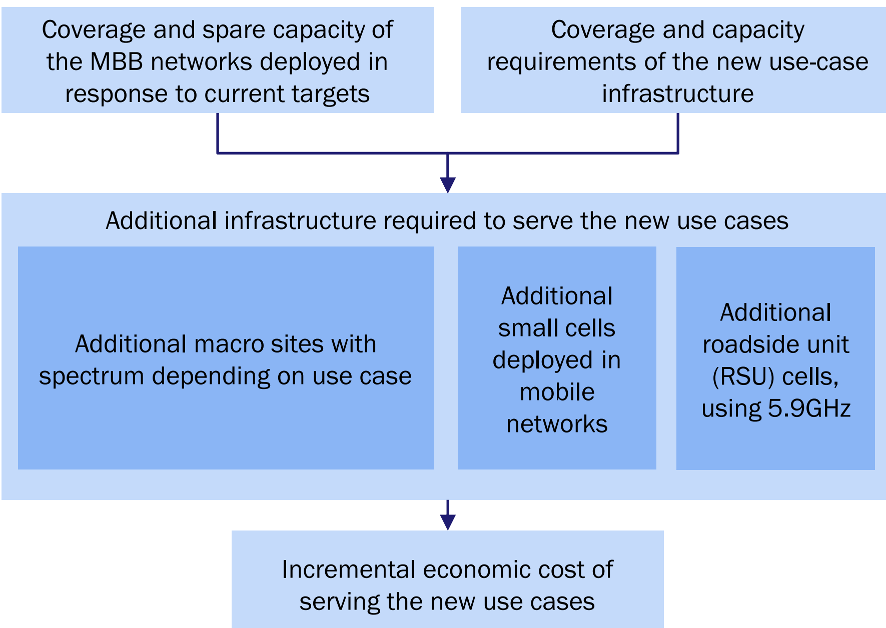
[2] We do not consider jobs created/displaced as part of our assessment

Source: Analysys Mason, Ericsson, Qualcomm

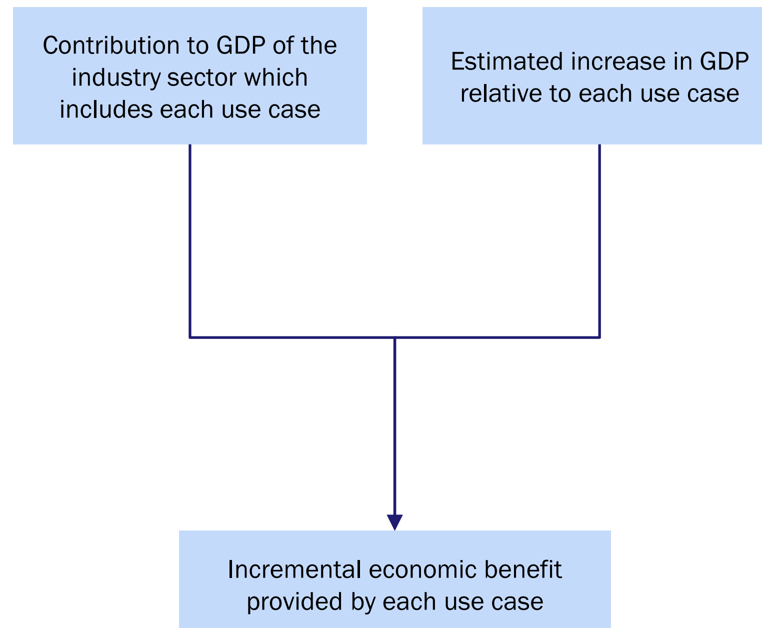
A quantitative estimate of economic benefits and costs is presented later in this section

To calculate the economic benefit, we built a model that estimates both the network costs and economic benefits of many of the use cases in each cluster

Calculation of the cost of providing the new use cases



Calculation of the benefits of new uses cases



The costs and benefits associated with the new use cases are calculated with reference to the 5G MBB networks assumed to be deployed as at 2025. Costs and benefits considered in the study are incremental to 5G MBB (costs and benefits associated with 5G MBB are not considered).

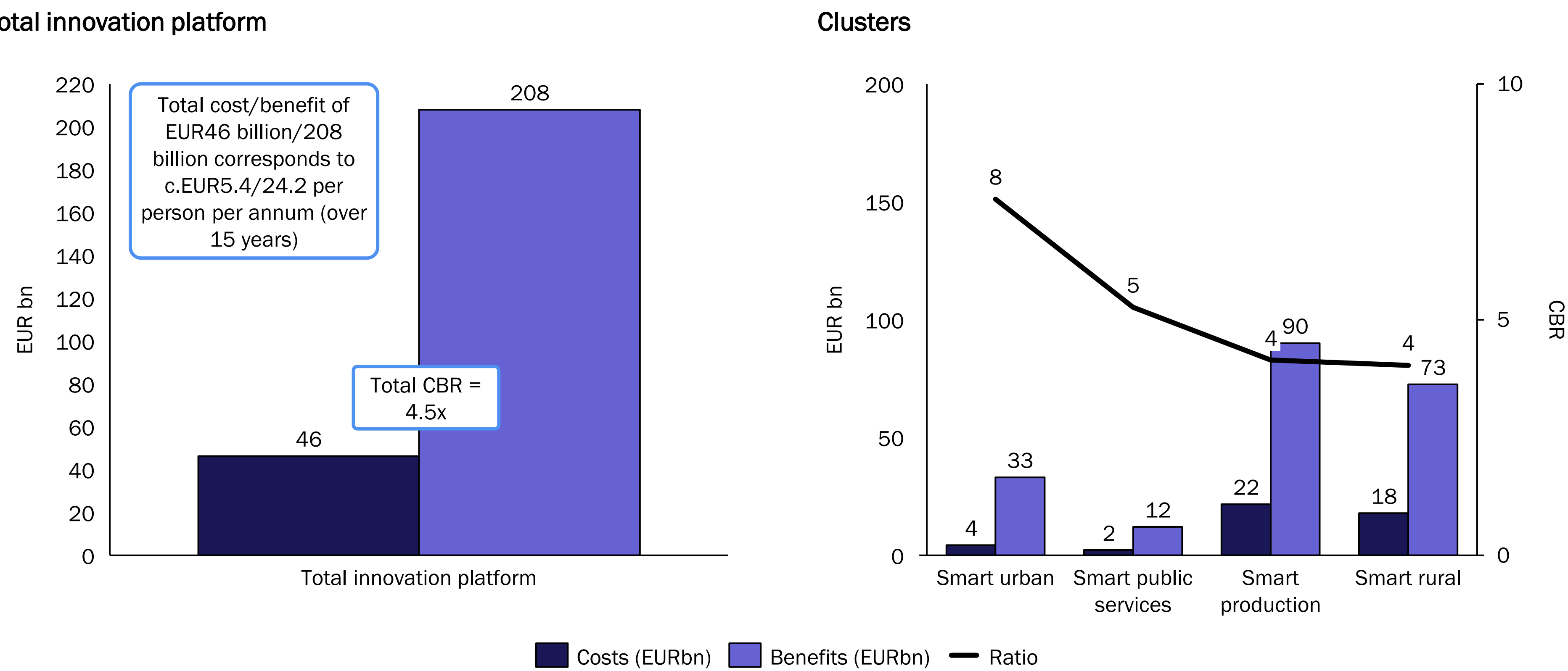
Characteristics of 5G MBB networks in 2025 assumed in the base case

5G coverage from existing low and lower-mid-band spectrum (e.g. 700MHz–2.6GHz)	Additional 5G capacity from mid-band spectrum (e.g. 3.5GHz)	Further 5G capacity from high-band spectrum (e.g. mmWave)
Deployment on up to 100% of sites assumed in base case	Deployment on all urban and suburban sites assumed in base case	Captured in use-case analysis

Source: Analysys Mason

As a total 'open innovation platform', 5G networks in Europe can deliver over EUR200 billion benefit, at c.EUR50 billion cost (4.5x ratio additional benefit vs cost)

5G upgrade cost, benefit and cost–benefit ratio (CBR), Europe

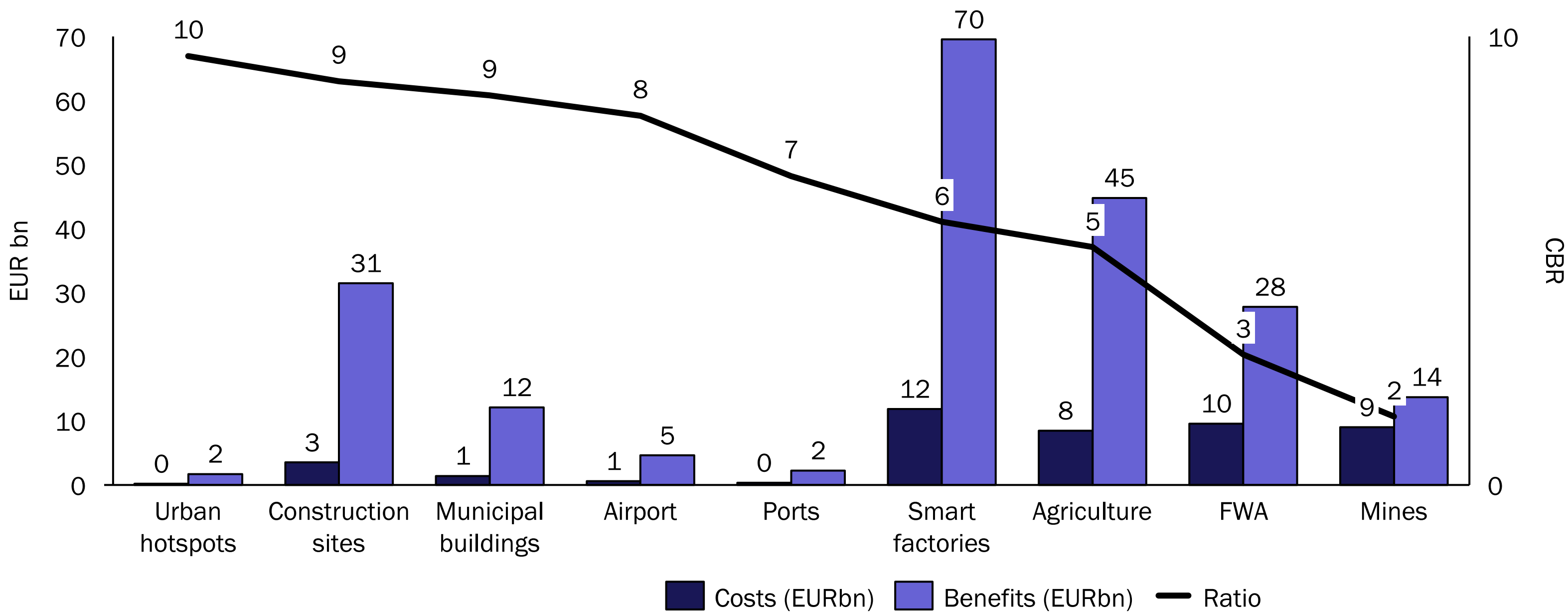


The benefits and costs shown here are in addition to the benefits leveraged from the initial 5G eMBB network investments in Europe – the benefits and costs shown here are for the expansion of 5G networks to 'full 5G' capability in accordance with our open innovation platform concept

Source: Analysys Mason

At the use case level, the largest economic benefits in terms of European GDP impact are from smart factory, agriculture and 5G FWA (suburban/rural broadband)

Use cases: 5G upgrade cost, benefit and CBR, Europe



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. We have considered the benefits of 5G to these use cases qualitatively in terms of the potential environmental and societal benefits (these include healthcare and hospitals, smart automotive and stadiums). We note consumer benefit will be generated from these use cases, which we have not modelled, but which several other published studies refer to.

- The costs and benefits shown are incremental to costs and benefits gained from initial 5G deployment (i.e. costs and benefits associated with our base case are not shown). "Total" benefit may be (significantly) larger than that shown when also including 5G benefits up to 2025 e.g. Analysys Mason modelling[1] for the 5GAA suggests c.EUR3–4 billion of European benefit from C-V2X (i.e. smart automotive) by 2025, rising to c.EUR20 billion by 2030, not shown here

We have assumed limited synergies between use cases due to localised demand and have not included any common cost from the MBB network (as we assume the MNOs will make 5G MBB available in any event, due to competitive pressure)

Note: FWA is assumed to serve 5–20% of broadband market in each country (guided by current propensity to use FWA services)

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

Many 5G use cases will be delivered by MNOs commercially: where investment is challenging, public subsides can help reduce costs/deployment barriers

5G use case and whether public funding is needed

Use case	Requires public funding
Smart factories	No
Mining	No
Ports	No
Airports	No
Freight and logistics	No
Energy and utilities	No
FWA	Yes[1]
Agriculture	Partly[2]
Construction	No
Urban hotspots including public transport	Partly[3]
Stadiums	No
Smart automotive	Yes
Healthcare and hospitals	Yes
Municipal buildings	Yes
Education	Yes
Tourism	Yes

- Many of the use cases we have considered as part of our full 5G assessment are expected to be deployed and paid for commercially in some environments (i.e. by MNOs on a commercial basis, independently of any EU/government targets)
- In other environments and for some types of deployment where the business case is challenging, use cases that are more likely to require public funding are shown in the table on the left
  - estimated public funding needs are included in the charts on the next slide

[1] 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).

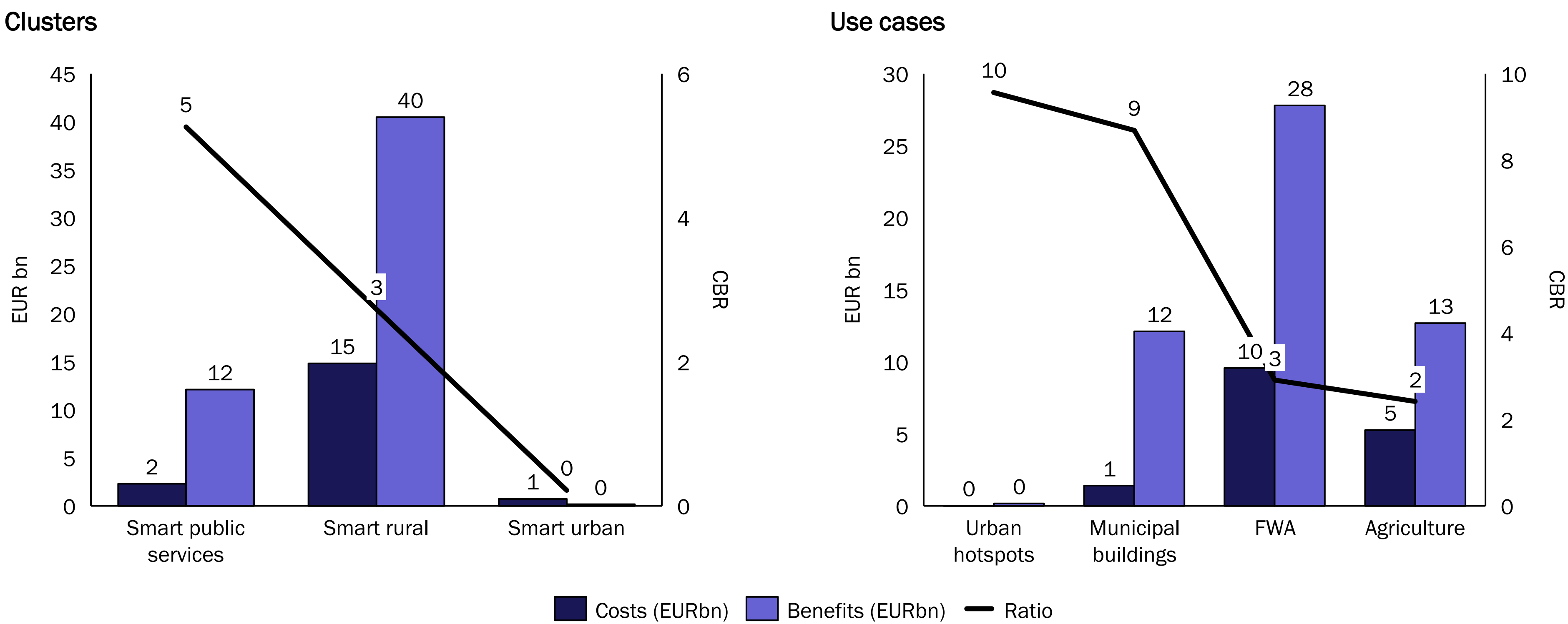
[2] We assume that the agricultural use case would be delivered commercially if the agricultural environment is within the coverage area of our modelled MBB networks. However, we assume that public subsidy would be required for agricultural environments outside the coverage area of our modelled MBB networks.

[3] 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.

Source: Analysys Mason

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 funding

5G upgrade cost, benefit and CBR, Europe – including only those use cases likely to require public funding

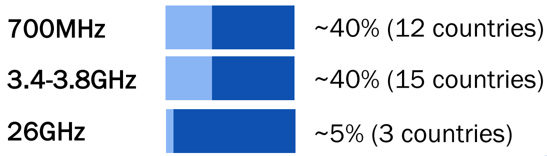


- Use cases requiring public funding for which we have modelled cost but not economic benefit (i.e. healthcare and hospitals and smart automotive) are not included in the right-hand chart above
- it is noted, however, that government funding for 5G infrastructure to support healthcare and hospitals, and autonomous vehicles, will be highly beneficial, based on previous studies

Source: Analysys Mason

In terms of GDP benefit, our modelling suggests European 5G policy should focus on 5G infrastructure for Smart Production and Logistics, together with Smart Rural

% of total 5G pioneer bandwidth awarded to date, European average[1]



Accelerate 5G rollout in line with 5GAP, including awarding spectrum in all 5G pioneer bands and timely rollout[2]

New priorities

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 mobile operators 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, including partnerships between governments and the mobile industry to deliver consistent 5G mobile coverage across rural locations (e.g. via shared deployment models) – including connecting 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 policy, including urban transport corridors	▪ Bring 5G into new and enhanced urban solutions through appropriate vertical policies (e.g. construction, transport, automotive) including edge computing and robotics ▪ 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 e.g. smart urban)
4	Smart public services policy	▪ Ensure public authorities can make specific 5G investments (e.g. in next-generation connectivity plans and funding), such as 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

[1] Straight average 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. Source: Analysys Mason

2 Commission recommendation on a common toolbox for reducing the cost of deployment, https://ec.europa.eu/digital-single-market/en/news/commission-recommendation-common-union-toolbox-reducing-cost-deploying-very-high-capacity

From an environmental and societal benefits perspective, high priorities are improving 5G coverage in the Smart Rural cluster, and factories, freight and logistics

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

Cell colours indicate benefit level: Highest benefit (green) – Agriculture (both rows), 5G FWA (societal), Ports (societal), Smart factories (both rows), Freight and logistics (environmental); Medium benefit (orange) – 5G FWA (environmental), Ports (environmental), Mines (both rows), Freight and logistics (societal), Energy and utilities (both rows); Lower benefit (yellow) – Airports (both rows).

Highest benefit Medium benefit Lower benefit

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Other priority policy areas from an environmental and societal benefits perspective include 5G infrastructure (to support smart automotive), and construction

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

Highest benefit (green: Smart automotive – Environmental; Construction sites – Environmental) Medium benefit Lower benefit

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Contents

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The overall aim of the study is to support a review and potential update of the 5G action plan in Europe, based on analysis of costs and benefits of ‘full 5G’ use cases

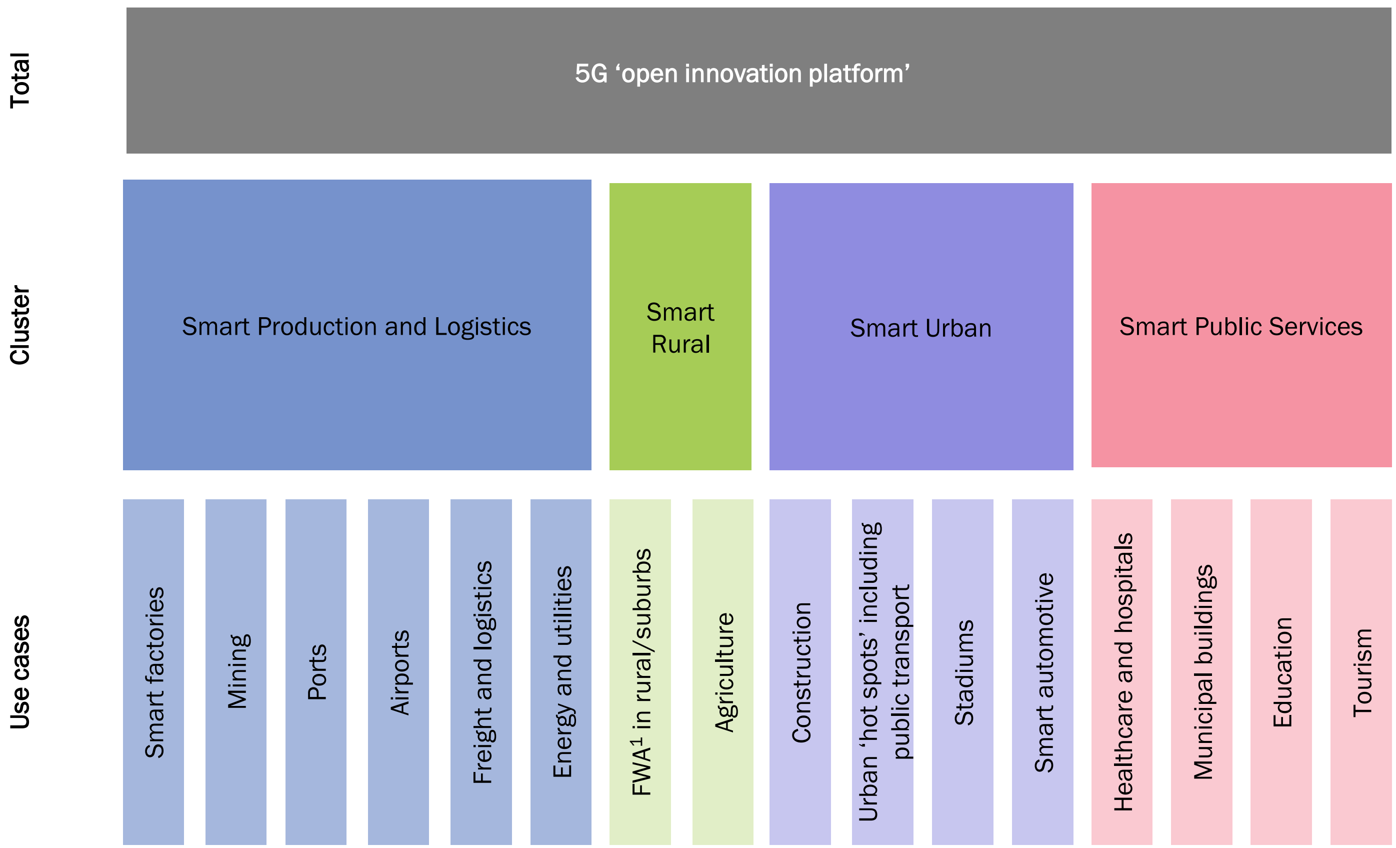
Aims of the study

- Ericsson and Qualcomm have commissioned Analysys Mason to conduct a study to help to define new 5G targets relevant to the European market
- The current targets are contained in the existing European 5G Action Plan (5GAP):
  - the 5GAP was aimed at launching initial 5G networks in Europe by 2020, and to promote 5G coverage 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
  - bands below 1GHz and the 3.5GHz band are being deployed both for 5G coverage, and for capacity
  - as per the 5GAP, higher bands (e.g. 26GHz) can also enable very high capacity in locations where traffic demand is highest, taking account of the diverse requirements for 5G use cases in different environments
- The aim of this study has been to provide a cost–benefit analysis to inform the development of updated European 5G goals (including releasing 5G’s full potential to aid 5G recovery post 2020), and taking account of experience from 5G trials, technology development and deployments since the 5GAP was developed back in 2016

Source: Analysys Mason

5G can be viewed as a flexible ‘open innovation platform’ supporting cross-sector use cases and environments, which we have grouped into ‘clusters’

Overview of the 5G open innovation landscape considered in the study



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’

It is useful to aggregate similar use cases into ‘clusters’ to align with different 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.

The study considers the social, environmental and economic benefits of these use cases, with quantified estimates of economic benefits

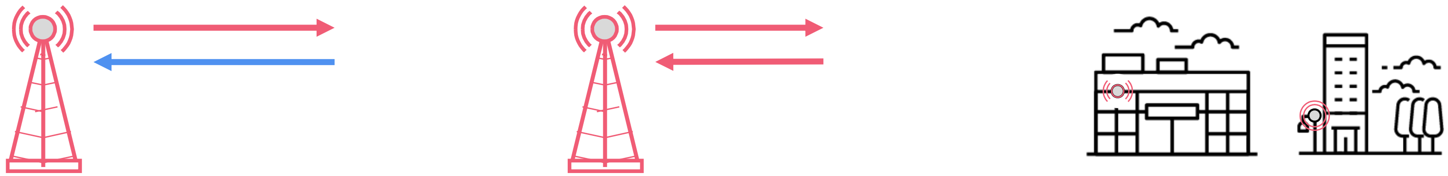
[1] Fixed-wireless access

Source: Analysys Mason

Our model considers three key network architectures, which capture a range of alternatives around the different deployments possible for new 5G use cases

Summary of key network architectures modelled

We have assumed DSS allows an SA architecture using mixed-frequency deployment[1]



Characteristics	5G macro cells (3.5GHz DL and low-frequency UL)	5G macro cells (3.5GHz DL and 3.5GHz UL)	5G small cells (3.5GHz or 26GHz) / 5G RSUs (5.9GHz)
Outdoor coverage	Local and wide area	Local and wide area	Localised
Indoor coverage	Possible within certain distance	Possible within certain distance	Can be installed inside buildings
Capacity	High downlink capacity	High uplink and downlink capacity	High-capacity and low-latency (both UL and downlink)
Typical uses	MBB, FWA, lower bandwidth new use cases	New use cases with requirement for reasonable coverage and high bandwidth	Very high traffic concentrations and/or specific coverage requirements

Many of the use cases will make uses of the characteristics of different architectures

Selected use cases	5G macro cells (3.5GHz DL and low-frequency UL)	5G macro cells (3.5GHz DL and 3.5GHz UL)	5G small cells / 5G RSUs
Smart factories		Coverage of factories with large site areas	Localised coverage for smaller factories
Ports and airports		High capacity coverage of large site area	
Agriculture	Wide area coverage of agricultural land		
Smart automotive	Coverage of major road transport routes		Localised transport coverage in urban areas e.g. intersections
Healthcare and hospitals			High-bandwidth, low-latency localised coverage

UL = uplink; DL = downlink; DSS = dynamic spectrum sharing; SA = standalone; RSU = roadside unit

[1] https://www.ericsson.com/en/blog/2019/7/standalone-and-non-standalone-5g-nr-two-5g-tracks, https://www.qualcomm.com/news/onq/2019/08/19/key-breakthroughs-drive-fast-and-smooth-transition-5g-standalone

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Contents

The cost–benefit approach compares the economic benefits to the additional costs of the new use cases via full 5G, beyond that of eMBB built on existing 4G networks

Overview of the cost–benefit modelling approach

- The study aims to compare the costs and benefits of new uses cases for 5G
- Three types of benefit are in scope:
  - economic benefit
  - social benefit
  - environmental benefit
- It is difficult to robustly **quantify** the social and environmental benefits of 5G
  - therefore the **quantitative** cost–benefit analysis considers the economic benefit against the costs
  - social and environmental benefits are considered on a **qualitative** basis
- The costs considered are those beyond what commercial operators will typically incur
  - this approach is described in detail on the right
- The model considers the costs and benefits across all countries in Europe, separately modelling the costs and benefits for each
- We consider several alternative deployments involving different spectrum, including localised deployment using mmWave

The reference case

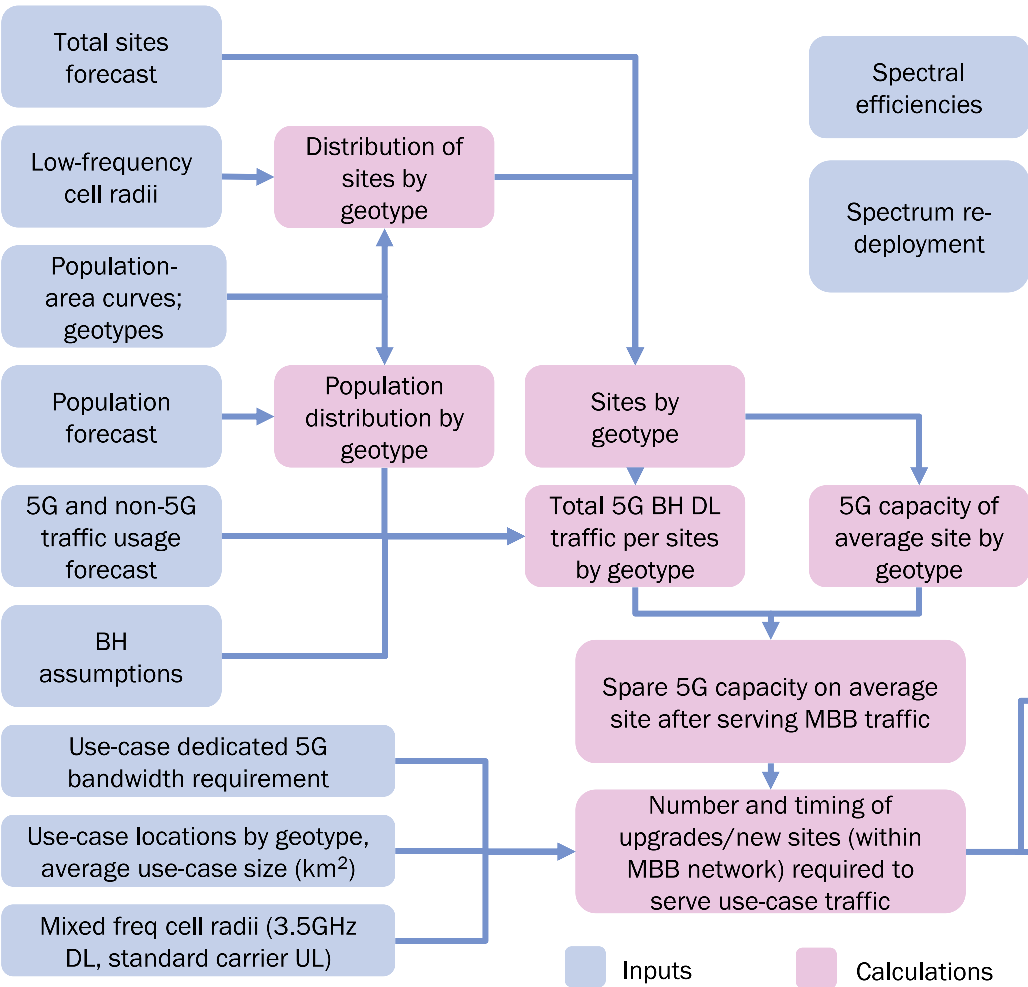
- The modelling considers the costs additional to what would be incurred by an initial commercial roll-out of 5G eMBB.[1] This approach is taken to estimate the public funding amount required to realise the benefits calculated in the study
- We assume it is highly likely that commercial operators will offer networks designed primarily for 5G MBB services on an ongoing basis due to consumer demand and competitive pressure but that some targeted investment is possible commercially, with other investments needing additional funding
- The study considers the additional costs for providing new use cases beyond MBB, and these are compared against the benefits of those use cases
  - under this approach, not all costs may need to be borne by public sector: commercial operators may choose to offer new use cases on a commercial basis to remain competitive (e.g. one operator deploys, others follow)
- It is not possible to estimate in detail the proportion of the costs related to the new use cases that will be provided on a commercial basis:
  - we do not know the extent to which commercial operators have taken strategic decisions to pursue certain roll-out and/or use cases
  - the commercial value of the new use cases is not yet well established, so we do not know what revenue may be derived, which would be required to calculate commercial viability
- However, we have estimated which use cases are more likely to require public funding vs those that are more likely to be deployed commercially. This allows us to present an estimate of the likely cost to public finances of those use cases that are likely to require funding

[1] As discussed subsequently, 5G is assumed to be deployed commercially on all existing sites by 2025 (via low-frequency spectrum), with higher-frequency 5G spectrum deployed on a subset of existing sites

Source: Analysys Mason

For use-case traffic served by 5G macro networks, the cost model calculates when (and how much) additional 3.5GHz capacity is needed for new use cases

Cost model structure for use-case traffic served over the existing macro network[1] via 5G capacity or 3.5GHz upgrades/new sites



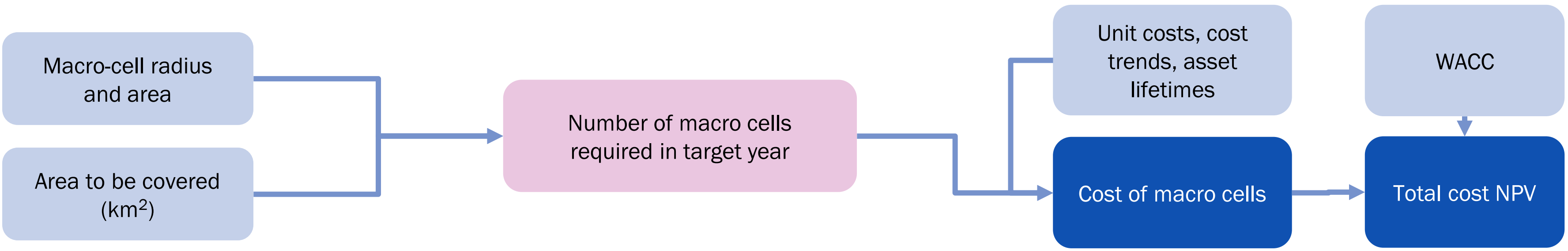
- The starting point of the macro network is 5G eMBB – we forecast how much capacity there will be on the eMBB network to carry use-case traffic, once MBB has been served
- FWA traffic served by the macro network is modelled separately from other use-case traffic
- Rather than specifying a dedicated 5G bandwidth requirement and calculating if this is available via existing capacity, FWA traffic is calculated in a bottom-up process (e.g. from a per-user forecast, BH assumptions) in a similar way to the MBB traffic
- This is then loaded onto the network after the MBB traffic, and any resultant capacity shortfall is addressed via site upgrades or new sites
- Note: for all use cases, we assume that there must be at least enough capacity on an average site (in each geotype) to serve the MBB traffic

Existing macro sites, where required, are deployed with 3.5GHz spectrum (i.e. 3.5GHz for DL and a standard carrier, e.g. 1800MHz, for UL). If further capacity is needed, a new 3.5GHz site is built. Sites are not upgraded with 3.5GHz UL spectrum; if a use case requires 3.5GHz UL capacity, then separate sites are built (see following slide)

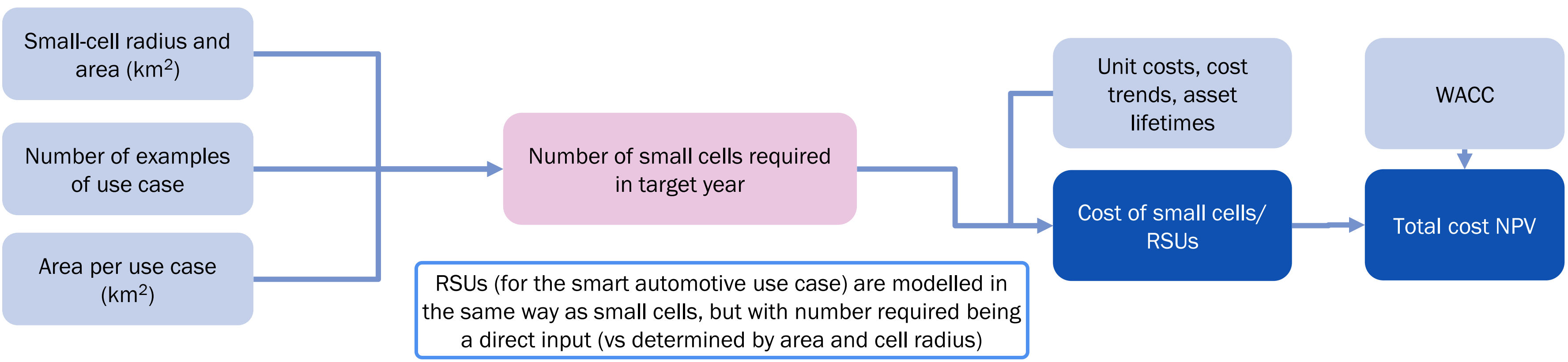
[1] In current MBB coverage areas. Source: Analysys Mason

The structure is much simpler for use-case traffic served by 3.5GHz macro cells in new locations or by cellular small cells, with RSUs for C-V2X

Cost model structure for use-case traffic served by extending the macro network via macro cells in new locations



Cost model structure for use-case traffic served by new small cells/RSUs[1]



For all use cases, the model calculates the costs (and benefits) on an individual country basis. A macro cycles through all countries, and aggregates costs to allow Europe-wide results to be calculated

Inputs Calculations Outputs

[1] Including mmWave spectrum in cellular network; RSUs assumed to use ITS spectrum (5.9GHz band). Source: Analysys Mason

Different 5G architectures might be used to deliver localised use cases, though for some use cases there are several alternatives

- The 5G network deployed by MNOs for eMBB purposes is the starting point for the modelling
- A mix of frequencies is assumed in the existing 5G network so that MNOs can largely re-use their existing grid of sites, and due to the downlink-heavy nature of eMBB traffic:
  - for the 5G downlink, 3.5GHz spectrum is used; combined with new massive MIMO (mMIMO) antenna technology which can be installed at the macro site, gives a significant capacity increase over a similar range to existing cell area
  - for the uplink, lower-frequency spectrum is assumed to be used, which is better suited to being used by mobile handsets and Internet of Things (IoT) devices
  - several legacy bands are also refarmed for 5G (both uplink and downlink) in 2025[1]
  - the mix of frequencies in the 5G RAN is still used when migrating to a 5G standalone architecture
  - 700MHz may serve use cases requiring high coverage but lower capacity – modelling assumes 3.5GHz cells are used throughout to deliver maximum speed and lowest latency
- An eMBB-focused network may not provide UL capacity suited to all use cases (see table) – we assume that some use cases need macro cells with 3.5GHz UL capacity

Analysis of architectures by use case

Use case	Suitable architecture
Smart factories	See next slide
Mining	See next slide
Ports	See next slide
Airports	See next slide
Freight and logistics	Cost not modelled
Energy and utilities	Cost not modelled
FWA	MBB-style macro cells (i.e. 3.5GHz for DL only), due to need for wide-area coverage, and heavy DL requirement
Agriculture	MBB-style macro cells (i.e. 3.5GHz for DL only), due to need for wide-area coverage, and light UL requirement
Construction	MBB-style macro cells (i.e. 3.5GHz for DL only), due to need for wide-area coverage and mobility
Urban hotspots including public transport	Small cells, due to intensity of demand. We assume that 26GHz is used outdoors for urban hotspots in urban centres, used to support several 5G traffic types
Stadiums	Small cells, due to intensity of demand
Smart automotive	Small cells for local coverage of junctions; wide- area coverage delivered by the MBB network Small cells for local C-V2X coverage at junctions are modelled as 5.9GHz RSUs[2]
Healthcare and hospitals	Small cells, due to requirement for indoor coverage, and high-reliability/low-latency requirements
Municipal buildings	Small cells, due to requirement for indoor coverage
Education & Tourism	Cost not modelled

[1] Legacy bands are not deployed on new MBB-style macro cells where these are needed (only 3.5GHz DL + lower frequency UL are deployed); [2] We assume RSUs can be co-located with MNO urban hotspot small cells (and can share backhaul, leading to cost synergies)

There are several use cases for which the type of architecture must be carefully considered based on the specific nature of the demand

Analysis of architecture requirements for smart factories, mining, ports and airports

Use case	Capacity considerations	Coverage considerations	Architecture assumptions
Smart factories	• IoT-type tracking of objects and status of machinery • High-volume video traffic for surveillance and monitoring • Low latency and high reliability for remote control of processes	• Indoor coverage, with many factory building walls made of metal and/or brick	• Some factories could be large enough to benefit from a new macro cell with 3.5GHz uplink, but we assume 90% will require small cells
Mining	• IoT-type tracking of vehicles and processes • Some video traffic for monitoring of processes	• Some open-cast mines may be coverable by macro cells, but other open-cast (and all underground) mines will require small cells	• Some open-cast mines could be oriented such that MBB coverage could be used, but 90% will require small cells
Ports	• IoT-type tracking of containers through port • High volume of video traffic for remote control of cranes and plant, and surveillance • Low latency and high reliability for driverless vehicles	• Outdoor coverage could be provided by macro cells, though stacks of metal containers could create propagation challenges	• Ports are covered by new macro cells using 3.5GHz in both the uplink and downlink
Airports	• IoT-type tracking of people and objects through the airport • High volume video traffic for maintenance monitoring and facial recognition • Low latency and high reliability for driverless loading/unloading vehicles around airplane parking spots	• Indoor coverage requirements for high-capacity demands	• Airports are covered by new macro cells using 3.5GHz in both the uplink and downlink

- The majority of locations for smart factories, mining, ports and airports will likely have a stronger uplink capacity requirement compared to consumer MBB
- This requirement is driven by a combination of factors, including high video demand, robotics and the need for low latency
- It is possible the benefits could be delivered without the use of 5G for real-time video and/or low latency (i.e. lower data rate IoT-type functions), but we have considered all use-case features, so we can consider a full estimate of the benefits[1]
- As per the earlier slide, smaller cells could use 26GHz and/or other mmWave bands instead of 3.5GHz, depending on the local requirements

[1] It is not possible to estimate what proportion of the benefits are attributable to which feature of the use case

The same set of network cost and network performance assumptions is used for all European countries

Network cost assumptions

Cost item	Unit capex (EUR)	Unit opex (EUR)
Site strengthening for mMIMO	24 000	1000
Site civils and acquisition – rooftop	35 000	5000
Site civils and acquisition - greenfield	90 000	5000
Macro site backhaul – microwave	15,000	8000
Macro site backhaul – fibre	30 000	2000
BBU	7500	–
3.5GHz mMIMO antenna	3125	–
3.5GHz mMIMO carrier	37 500	625
Non-mMIMO antenna (all bands)	7500	–
Standard UL carrier (e.g. 1800MHz)	4000	120
Small cell (26GHz/mmWave)	4000	400
C-V2X RSU (5.9GHz)	2000	200
Small cell or RSU backhaul[1]	200	20
5G core	10% of RAN	

Passive sharing can be switched on in model: passive costs associated with a new site or site upgrade (site civils and acquisition, site strengthening and backhaul) are halved (represents passive network sharing between two MNOs)

Network performance assumptions

Assumption	Details
Spectral efficiencies	• 'Baseline' 4G efficiency (per sector) of 3.3bit/s/Hz in 2020, increasing to 3.7bit/s/Hz in 2034 • Increase by factor of 1.2 for 5G, and a further factor of 5.0 for 5G + mMIMO (3.0 if non-urban geotype) • Various adjustments made, e.g. for maximum utilisation of carriers, sector non-homogeneity and geotype-specific adjustments • Final spectral efficiencies vary significantly: 5G + mMIMO (urban): 12.7bit/s/Hz in 2020 increasing to 16.1bit/s/Hz in 2034. 4G (rural): 1.5/s/Hz in 2020 increasing to 1.7bit/s/Hz in 2034
MBB traffic	• Traffic distributed by geotype according to the population which is covered by the MBB network • 12% MBB data traffic assumed to fall in MBB busy hour (BH)
FWA traffic	• MNO wins 5–20% of premises which have fixed broadband (FBB) but are not covered by FTTH (and are covered by the MBB network) in each geotype • Total % of premises covered by FTTP is an input; these premises are assigned to the most urban geotypes • 10% of FWA data traffic assumed to fall in the FWA BH (reduced from 12% MBB value, accounting for increased spectral efficiency and lower 'peaky-ness' of FWA traffic) • 80% reduction of FWA BH traffic to convert to MBB BH

Note: network cost and performance assumptions are based on Analysys Mason's European cost modelling experience

Asset lifetimes and cost trends have been assumed based on Analysys Mason modelling experience. A discount rate (WACC) of 6.0% is assumed for discounting total benefits and costs

[1] We assume that RSUs can be co-located with MNO urban hotspot small cells, and that cost synergies arise from shared backhaul between these two use cases

We use the same set of cell-radii assumptions for all markets, but we account for market-specific variations such as the amount of 3.5GHz spectrum available

Spectrum

Band	Total in market	Long-term deployment	Deployment technology
700MHz	2x30MHz	All sites	5G
800MHz	2x30MHz	All sites	4G
900MHz	2x30MHz	All sites	3G, refarmed to 5G in 2025
1400MHz	80MHz	60% of sites	4G
1800MHz	2x75MHz	All sites	4G, refarmed to 5G in 2025
2100MHz	2x60MHz	All sites	3G, refarmed to 5G in 2025
2300MHz	80MHz	60% of sites	4G, refarmed to 5G in 2025
2600MHz FDD	2x70MHz	60% of sites	4G, refarmed to 5G in 2025
2600MHz TDD	50MHz	60% of sites	4G, refarmed to 5G in 2025
3500MHz	Country dependent	All urban and suburban sites[1]	5G + mMIMO

- MNO spectrum holdings are calculated by dividing total spectrum in the market by the number of MNOs
- We do not assume that any new spectrum bands (e.g. 6GHz) are made available for serving MBB traffic during the modelling period. The resultant (potential) under estimate of available capacity is offset by tempering our long-term mobile traffic forecast
- An incremental roll-out of certain spectrum bands is assumed in the early years of the model, but it is the long-term level of deployment (beyond the target year of 2025) which is important for the cost

Cell radii (km)[1]

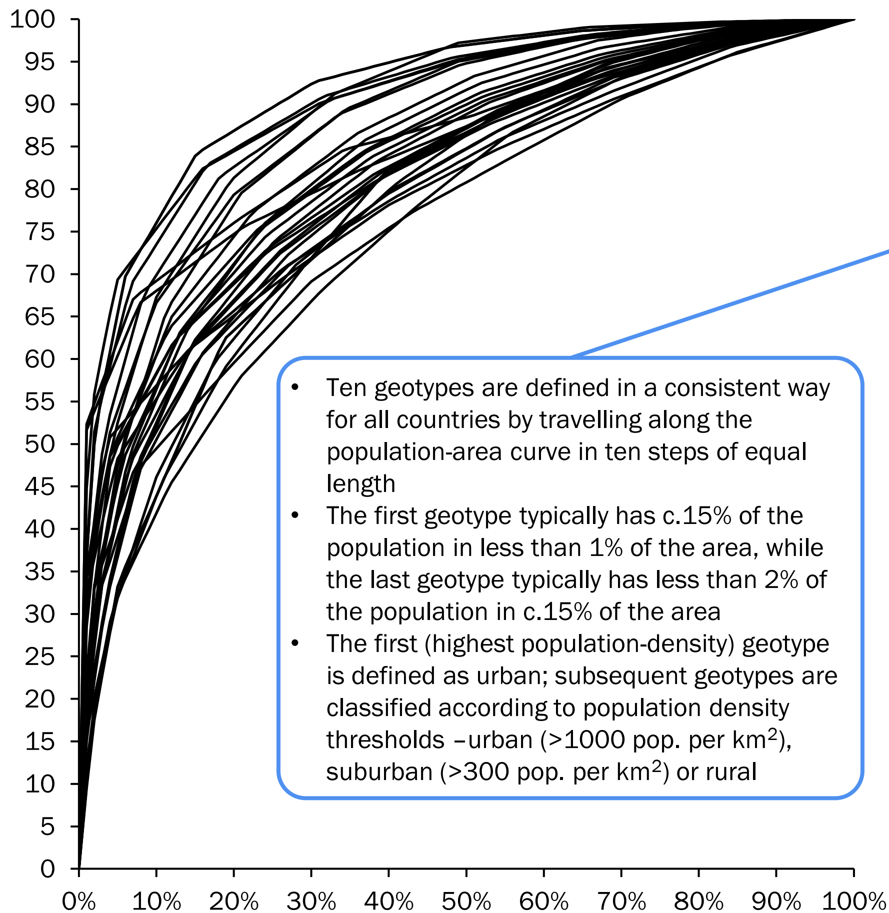
Technology	Geotype	Mixed freq with mMIMO	3.5GHz UL and DL with mMIMO	Small cell (3.5GHz or 26GHz)
MBB	Urban	0.4	0.6	0.1
	Suburban	0.9	0.6	0.1
	Rural	3.6	0.6	0.1
FWA	Urban	1.6	N/A	N/A
	Suburban	3.6	N/A	N/A
	Rural	14.4	N/A	N/A

- Our cell radii assumptions are designed to provide a coverage layer and do not include the impact of subsequent additional infill cells for capacity
- FWA cell radii are assumed to be a factor of 4 greater than MBB cell radii
- Cell areas are calculated from cell radius using a 'cell pi' of 1.95. This is the area of three tessellated regular hexagons inscribed by a circle of radius 1 (i.e. the cell pi models a tri-sector cell)
- New macro cells with 3.5GHz UL and DL are used in specific locations (large factories, ports, airports) have the same cell radius across geotypes
- Small cells are also used in specific locations and thus also have the same call radius across geotypes

[1] The resulting population coverage varies by country (with an average of c.50%). [2] Low-frequency MBB cell radii (1.2/2.3/7.0km for urban/suburban/rural geotypes respectively) are also used, but only to calculate the distribution of sites by geotype. The number of sites required to provide services outside of the existing MBB network is driven by the 3.5GHz cell radii

We vary a number of parameters by country: population-area curves, geotypes, population/traffic forecasts, amount of 3.5GHz spectrum, number of existing sites

Population-area curves for European countries



- Ten geotypes are defined in a consistent way for all countries by travelling along the population-area curve in ten steps of equal length
- The first geotype typically has c.15% of the population in less than 1% of the area, while the last geotype typically has less than 2% of the population in c.15% of the area
- The first (highest population-density) geotype is defined as urban; subsequent geotypes are classified according to population density thresholds –urban (>1000 pop. per km^2), suburban (>300 pop. per km^2) or rural

Assumptions/inputs for cost calculations

Assumption	Source
Population-area curves	Eurostat[1] (see chart on the left)
Resulting geotypes	Calculated from population-area curves and geotype definitions
Population forecast Premises forecast	Analysys Mason Research division
Number of MNOs Mobile population penetration Mobile data traffic per connection % of connections that are 5G 5G-to-4G traffic usage ratio	Analysys Mason Research division
% of premises passed by FTTP FWA data traffic per connection FBB household penetration[2]	Analysys Mason Research division
Area of country (km^2) Household mobile coverage	European Commission, Broadband Coverage in Europe 2019[3]
3.5GHz spectrum forecast	NRAs
Number of sites	NRA site databases, Analysys Mason project work. Sites per population of known countries calculated and used where data is not available

Model forecasts have been extended to 2040, where required. Where data is not available for an individual country, the Central and Eastern Europe (CEE) or Western Europe (WE) average has been used

[1] See https://ec.europa.eu/eurostat/web/nuts/local-administrative-units.

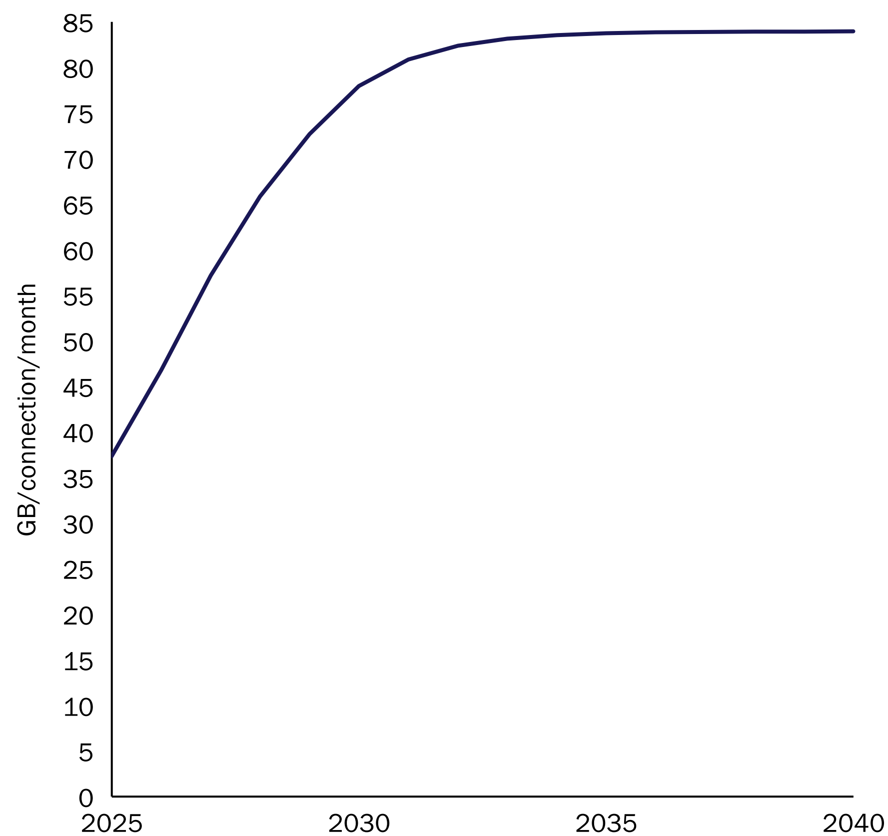
[2] FWA connections as % of FBB connections based on data from Analysys Mason Research division

[3] See https://digital-agenda-data.eu/

Different mobile traffic forecasts have been developed for each country, which at an aggregate European level align with the Ericsson's Mobility Report

- Mobile traffic usage from 2025 onwards is an important input to the model (for use cases served over the macro network)
- The Ericsson Mobility forecast was published in June 2020[1]
  - average mobile traffic per smartphone per month is forecast to increase from 5.8GB in 2019 to 24GB in 2025 in CEE, and from 8.2GB to 36GB in WE
- We have developed mobile handset/smartphone and commercial FWA[2] traffic forecasts from 2025, on an individual country basis, such that the overall European average for 2025 is roughly in line with the Ericsson Mobility forecast for 2025
  - variation between countries is based on Analysys Mason Research data (i.e.. historical mobile usage by country)
  - we have modelled limited growth beyond 2030 that may underestimate the level of network congestion in later years, if there was to be a continued steep increase in GB/connections/month
    - this is offset by assuming that no additional spectrum is released into the market during the modelling period (which would tend to over-estimate the level of network congestion)

Mobile data usage forecasts, weighted average across all European countries modelled[3]



[1] See https://www.ericsson.com/en/mobility-report/reports/june-2020/mobile-data-traffic-outlook; [2] We include commercially viable FWA traffic in these forecasts, since our FWA use case concerns non-commercially viable FWA traffic; [3] Chart includes both downlink (DL) and uplink (UL) traffic. This is converted to DL only for modelling purposes. It is assumed that DL traffic forms 85% of the total

The number of locations of each use case (by country) has been derived from various sources, and the typical area (km^2) of use cases has been estimated [1/2]

Summary of location assumptions by use case

Cluster	Use case	Source of number of locations	Area per location	Number of cells needed for coverage		
				Mixed freq macro	3.5UL macro	Small cells
Smart Production and Logistics	Ports	• Eurostat: Gross weight of goods transported to/from main ports (thousand tonnes). Link. • Only included ports where this metric exceeded 2m tonnes per annum in 2018	c.2km × 2km	N/A	6	N/A
	Airports	• Eurostat: Commercial airports with more than 15 000 passengers per annum. Link				
	Mines	• Eurostat: Number of mines/quarry enterprises by number of employees, 2017. Link • Assumed mapping between enterprise size and number of 5G mines	c.1km × 1km	c.4/1/1 urban/suburban/ rural geotypes [10% of locations]	N/A	c.50 [90% locations]
	Smart factories	• Eurostat: Number of manufacturing enterprises by number of employees, 2017. Link • Assumed mapping between enterprise size and number of 5G factories	c.200m × 200m	N/A	1 [10% locations]	3 [90% locations]
	Freight/logistics	No economic benefit modelled				
	Energy/utilities	No economic benefit modelled				
Smart Rural	Agriculture	• Eurostat: Farms and farmland in the European Union. Link • Assumed total "utilised agricultural area" to be covered (5G)	N/A – use case distributed over large area			
	FWA	• FWA assumed to serve 5–20% of broadband market in each country (guided by current propensity to use FWA services)[1] • FWA traffic assumptions, FTTP coverage, market share etc. determine traffic to be served in existing MBB network footprint	N/A – use case distributed over large area			

[1] 20% is assumed in Czechia, Slovakia, Austria, Poland, Finland; 10% is assumed in Croatia, Lithuania, Bulgaria, Portugal, Italy, Serbia; 5% is assumed in all other countries. Source: Analysys Mason

The number of locations of each use case (by country) has been derived from various sources, and the typical area (km^2) of use cases has been estimated [2/2]

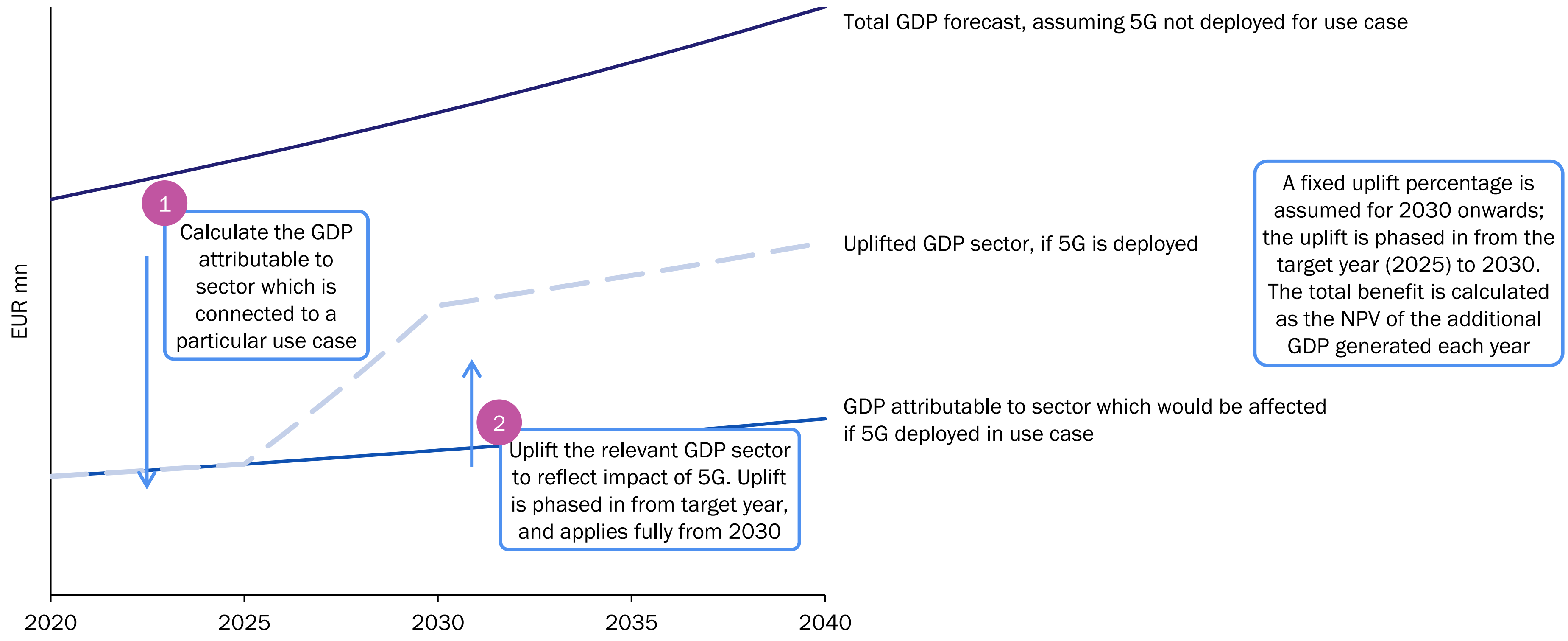
Summary of location assumptions by use case

Cluster	Use case	Source of number of locations	Area per location	Number of cells needed for coverage		
				Mixed freq macro	3.5UL macro	Small cells
Smart Urban	Smart automotive	• Number of traffic lights in cities >200 000 population calculated for France, Germany and the UK (based on previous Analysys Mason project work) • This is used to estimate a value for RSUs per pop. (then used for all countries)	N/A – RSU is a direct input (see left)			
	Urban hotspots including public transport	• All cities >200 000 population qualify for urban hotspots (1 per 20 000 population) • Cities by population taken from Link	c.300m × 300m	N/A	N/A	5
	Stadiums	• All stadiums with capacity over 10 000 • Data from worldstadiums.com. Link	c.200m × 200m	N/A	N/A	3
	Construction sites	• Eurostat: Number of construction enterprises by number of employees, 2017. Link • Assumed mapping between enterprise size and number of 5G construction sites	c.200m × 200m	1	N/A	N/A
Smart Public Services	Healthcare and hospitals	• World Health Organisation (WHO). Link • Total number of hospitals for most recent year available (up to 2014)	c.400m × 400m	N/A	N/A	9
	Municipal buildings	• Estimates based on previous Analysys Mason project work (data extrapolated from data points for UK/France/Spain/ Italy)	c.50m × 50m	N/A	N/A	1
	Education	No economic benefit modelled				
	Tourism	No economic benefit modelled				

Source: Analysys Mason

Economic benefit is calculated by estimating (1) the GDP of the sector which is connected to a particular use case, and (2) the uplift to sector GDP if 5G is deployed

GDP forecast: two-step process for calculating economic benefit of deploying 5G in a particular use case



In some cases an alternative process is used (FWA and urban hotspots), or no economic benefit is modelled (healthcare and hospitals, smart automotive, and stadiums). See the following slide for details of each use case

Note: GDP forecasts up to 2024 are from the IMF's World Economic Outlook Database. As of June 2020, this GDP data takes account of the impact of the COVID-19 pandemic on an individual country level. Beyond 2024, a growth rate has been applied that is equal to the pre-COVID forecast CAGR between 2019 and 2024).

Our assumptions for GDP share and 5G-induced uplift have been developed based on range of public sources [1 of 2]

Summary of economic benefits assumptions by use case

Cluster	Use case	GDP of sector (as % of total GDP) (1)	Uplift of relevant GDP sector (2)
Smart Production and Logistics	Ports	• Assumed to be 0.1% of GDP in all countries • Informed by 2016 EC Report "Maritime transport in the EU". Link	3.0%
	Airports	• Assumed to be 0.2% of GDP in all countries • Informed by statistic published by aviationbenefits.org. Link	3.0%
	Mines	• World Bank: coal + mineral rents as % of GDP. Link. Link. • Varies by country; typically very small (<0.1%)	1.8%
	Smart factories	• Eurostat: GVA by sector (used as proxy for share of GDP). Link • 'Manufacturing' sector, reduced by the estimated proportion of manufacturing enterprises that are large enough and in an appropriate sub-sector to be able to benefit from 5G	1.0%
	Freight and logistics	• N/A – No economic benefit modelled*	No economic benefit modelled
	Energy and utilities	• N/A – No economic benefit modelled*	No economic benefit modelled
Smart Rural	Agriculture	• Eurostat: GVA by sector (used as proxy for share of GDP). Link • 80% of "Agriculture, forestry and fishing" sector; varies by country	2.6% As above
	FWA	• N/A – Economic benefit modelled as overall GDP uplift	• Modelled as overall GDP uplift of 1%, multiplied by % of total premises with 5G FWA • Informed by "Superfast Broadband Programme Evaluation. Annex B: Economic Impacts", Ipsos MORI technical paper (2018). Link

Based on published reports which provide estimates of sectoral GDP uplifts as a result of 5G in 2030.

We have drawn particularly on two reports: "5G socio-economic impact in Switzerland" (Tech4i2, 2019 - Link) and "$1.4tn of benefits in 2030: 5G's impact on industry verticals" (STL Partners, 2019 - Link). We have generally adopted values from the first of these two reports, which has more conservative estimates of GDP impact[1]

* Economic benefits are not modelled if there is limited 5G-specific economic benefit/the benefits are captured by existing targets.

[1] As part of our analysis, we have read several other reports regarding the economic impact of 5G: "5G economic impact study 2019" (HIS Markit), "Mobile Economy 2020 APAC" (GSMA) and "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe" (EC)

Our assumptions for GDP share and 5G-induced uplift have been developed based on range of public sources [2 of 2]

Summary of economic benefits assumptions by use case

Cluster	Use case	GDP of sector (as % of total GDP) (1)	Uplift of relevant GDP sector (2)
Smart Urban	Smart automotive	• N/A – No economic benefit modelled* • Economic benefit is not quantified for the smart automotive use case, as we understand the benefit of NR C-V2X over LTE C-V2X to be primarily related to additional safety. This benefit is captured as a social benefit (see subsequent slide)	No economic benefit modelled
	Urban hotspot including public transport	• N/A – Economic benefit modelled as overall GDP uplift, including impact of connected urban public transport	Modelled as overall GDP uplift of 1% × a reduction factor to adjust for the number of people and time spent in hotspots
	Stadiums	• N/A – No economic benefit modelled* • Economic benefit is not quantified for the stadiums use case, as we understand the benefit of NR over LTE to be primarily related to improved consumer experience. This benefit is captured as a social benefit (see subsequent slide)	No economic benefit modelled
	Construction sites	• Eurostat: GVA by sector (used as proxy for share of GDP). Link • "Construction" sector, reduced in accordance with 5G site mapping; varies by country	2.4%
Smart Public Services	Healthcare and hospitals	• N/A - No economic benefit modelled • Economic benefit is not quantified for the healthcare and hospitals use-case, as we understand the benefit of NR over LTE to be primarily environmental and social (see later slides)	No economic benefit modelled
	Municipal buildings	• Eurostat: GVA by sector (used as proxy for share of GDP). Link • 5% of "Public administration, defense, education, human health and social work activities" sector; varies by country	1.0%
	Education	• N/A – No economic benefit modelled	No economic benefit modelled
	Tourism	• N/A – No economic benefit modelled	No economic benefit modelled

Callout (uplift column, pointing to 2.4%): Based on published reports which provide estimates of sectoral GDP uplifts as a result of 5G in 2030; see previous slide for details

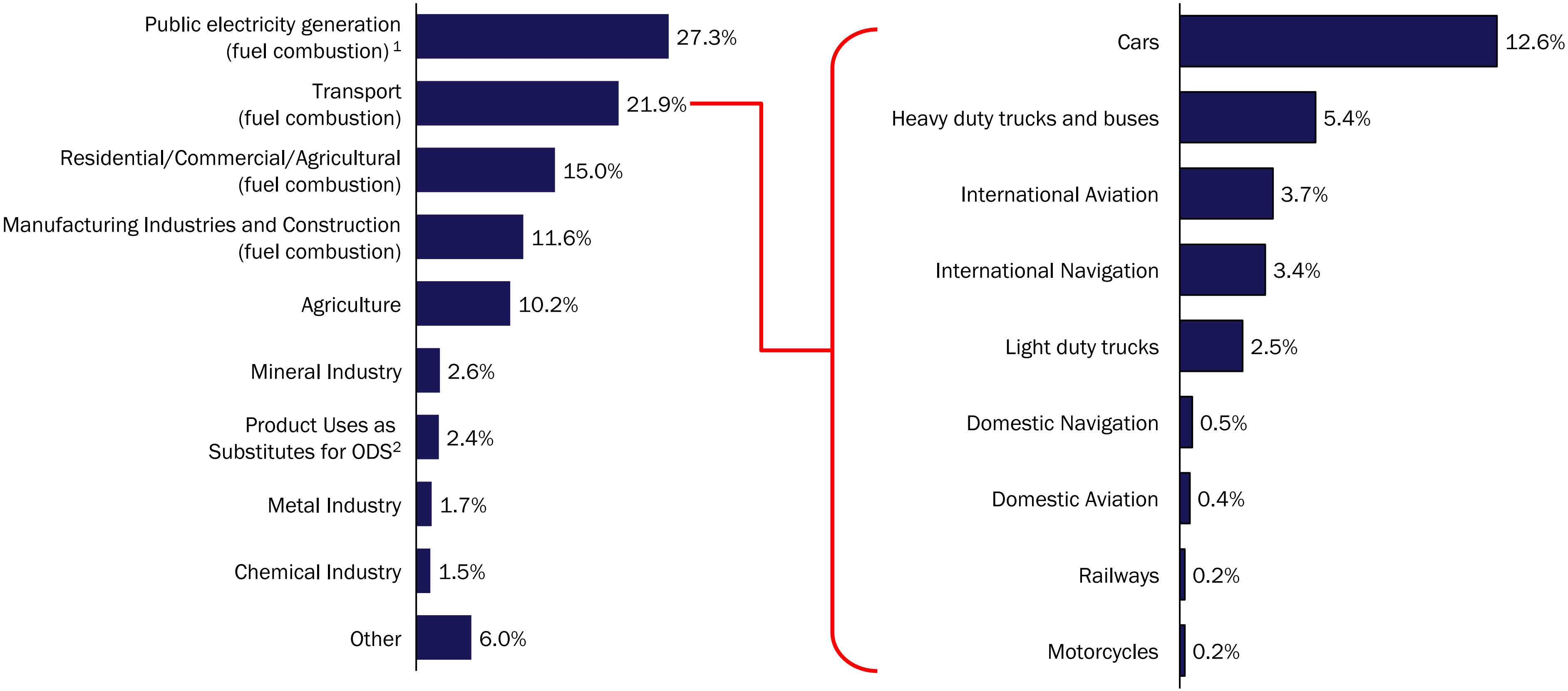
Callout (uplift column, pointing to 1.0%): Conservative estimate, informed by other similar sectors

* Economic benefits are not modelled if there is limited 5G-specific economic benefit/the benefits are captured by existing targets.

Source: Analysys Mason

Our environmental benefit assessment has been informed by data on greenhouse gas (GHG) emissions in Europe by sector

Share of total GHG emissions in Europe, by sector | **Share of total GHG emissions in Europe, transport sector**



- Nearly 80% of GHG emissions in Europe arise from fuel combustion
- The energy sector (generation of public electricity) and the transport sector are the largest contributors (c.27% and c.22% respectively)

[1] Includes fuel combustion associated with fuel manufacture (e.g. petrol refinery); [2] Ozone depleting substances

Source: EEA GHG data viewer; see https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

Our environmental and societal benefit assessments have also been informed by a number of publicly available studies

Studies relating to environmental and social impact of 5G used to inform our analysis

Source (date published)	Title	Link
Huawei (August 2020)	Green 5G: Building a sustainable world	https://www.huawei.com/en/public-policy/green-5g-building-a-sustainable-world
World Economic Forum (January 2020)	The Impact of 5G: Creating New Value across Industries and Society	https://www.weforum.org/whitepapers/the-impact-of-5g-creating-new-value-across-industries-and-society
GSMA (December 2018)	Study on Socio-economic benefits of 5G services provided in mmWave bands	https://www.gsma.com/spectrum/wp-content/uploads/2019/10/mmwave-5G-benefits.pdf
Vodafone (February 2018)	Creating a Gigabit Society – The Role of 5G	https://www.vodafone.com/content/dam/vodcom/files/public-policy/gigabit-society-5g-04042017.pdf
Centre for Technology Innovation (December 2016)	Achieving sustainability in a 5G world	https://www.brookings.edu/research/achieving-sustainability-in-a-5g-world/
European Commission (August 2016)	Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe	https://connectcentre.ie/wp-content/uploads/2016/10/EC-Study_5G-in-Europe.pdf

Source: Analysys Mason

5G connectivity could help deliver environmental benefits in smart factory, freight and logistics and agriculture uses cases via real-time, precision processes

Assessment of environmental benefit created by 5G, by use case

Cluster	Use case	Environmental benefit of 5G	GHG contribution	Potential for 5G to enhance services/create new opportunities	Assessment
Smart Production and Logistics	Ports	▪ Reduced carbon emissions through greater logistic efficiency	Medium	◕	Medium
	Airports	▪ Reduced congestion	Medium	◐	Lower
	Mines	▪ Better air quality monitoring/reduced risk of hazards (environmental monitoring within mines)	Medium	◕	Medium
	Smart factories	▪ Better utilisation of time and materials/reduced energy consumption ▪ Environmental monitoring in industrial processes (improved lifetime of equipment)	Medium	●	High
	Freight and logistics	▪ Efficient 'just-in-time' supply chains, reducing unnecessary journeys and transportation of goods	Medium	●	High
	Energy	▪ Better management of energy consumption, by more closely matching supply and demand ▪ Reduced GHG emissions from remote monitoring and reduced in-person inspection	High	◐	Medium
Smart Rural	Agriculture	▪ 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	Medium	●	High
	FWA	▪ Reduced journeys (e.g. from being able to work remotely)	Low (total cars have high GHG contribution but lower vehicle density in rural)	●	Medium

Key: ◐ Could use other wireless solutions ◕ Good ● Very good fit

5G could also contribute to environmental benefits via providing real-time connectivity for the smart automotive and construction use cases

Assessment of environmental benefit created by 5G, by use case

Cluster	Use case	Environmental benefit of 5G	GHG contribution	Potential for 5G to enhance services/create new opportunities	Assessment
Smart Urban	Smart automotive	▪ Fuel efficiency and reduced emissions (e.g. from having access to real-time map updates, real-time parking data, making journeys shorter)	High	Good	High
	Urban hotspot	▪ Reduced emissions from optimised public transport networks ▪ Smart buildings/green building initiatives ▪ More efficient public transport journeys/reduced pollution	Medium	Good	Medium
	Stadiums	▪ Support for green initiatives in stadiums	Low	Could use other wireless solutions	Lower
	Construction sites	▪ Better energy use/less waste ▪ Support for green construction practices (e.g. remote management of machines)	High	Very good fit	High
Smart Public Services	Healthcare and hospitals	▪ Reduced journeys (e.g. ambulances to hospitals or journeys to GP surgeries)	Low	Good	Lower
	Municipal buildings	▪ Possible reduction in journeys (e.g. fewer journeys for monitoring and resolving social problems)	Medium	Good	Medium
	Education	▪ Green school initiatives (e.g. high-speed, low-latency connectivity to support energy-saving or environmental projects in schools or universities)	Low	Good	Lower
	Tourism	▪ Conservation benefits (e.g. enabling tourists to better understand environmental challenges via VR/AR)	Low	Very good fit	Medium

Key: Could use other wireless solutions; Good; Very good fit

Our assessment is the highest societal benefit from 5G is potentially in the smart production and logistics, and smart rural clusters

Social benefit assessment, by use case

Cluster	Use case	Social benefit	Aligned with EU policy goals	Potential for 5G to enhance services/create new opportunities	Impact assessment
Smart Production and Logistics	Ports	▪ Increased security; technologically skilled workforce	✔✔✔	◕	High
	Airports	▪ Increased security/safety; less time spent waiting in airports ▪ Wellbeing (from increased security and enhanced passenger experience)	✔	◑	Lower
	Mines	▪ Increased security; technologically skilled workforce	✔	◕	Medium
	Smart factories	▪ Increased security/safety; technologically skilled workforce	✔✔	●	High
	Freight and logistics	▪ Increased safety	✔	●	Medium
	Energy	▪ Encouraging good energy behaviour	✔✔✔	◑	Medium
Smart Rural	Agriculture	▪ Rural sustainability (support for local farmers in remote areas) ▪ Ability of farmers to market products beyond local area (e.g. using e-commerce platforms)	✔✔	●	High
	FWA	▪ Increased social inclusion; reduced digital divide ▪ Could slow or even reverse the 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	✔✔	●	High

Key: ◑ Could use other wireless solutions ◕ Good ● Very good fit

✔✔✔ Strong alignment with EU policy goals ✔✔ Good alignment ✔ Not highest EU priority

The smart urban and smart public service clusters will also benefit from 5G to deliver societal benefits including safety, wellbeing, inclusion and education

Social benefit assessment, by use case

Cluster	Use case	Social benefit	Aligned with EU policy goals	Potential for 5G to enhance services/create new opportunities	Impact assessment
Smart Urban	Smart automotive	▪ Safety related (e.g. reduction in accidents) ▪ Optimising driving patterns/reducing journey time (wellbeing benefit)	✔✔	◕	Medium
	Urban hotspot, including public transport	▪ Wellbeing benefits for those living in cities: better access to e.g. entertainment/e-commerce while travelling ▪ Lower journey times on public transport/increased safety/better information	✔✔	◕	Medium
	Stadiums	▪ Enjoyment/experience (ability to replay live video, interact with the event, etc.) ▪ Additional viewing content (e.g. behind the scenes)	✔	◑	Lower
	Construction sites	▪ Increased safety of building sites	✔	●	Medium
Smart Public Services	Healthcare and hospitals	▪ High reliability remote consultation and triage ▪ Increase social inclusion and wellbeing; improved care	✔✔	◕	Medium
	Municipal buildings	▪ Collaboration/interaction (e.g. social or business hubs)	✔✔	◕	Medium
	Education	▪ Increased availability and access to education, including remote learning in schools and universities ▪ Remote access to experts	✔✔	◕	Medium
	Tourism	▪ Virtual walk-throughs of tourist sites/quality of experience ▪ Educational benefits	✔	●	Medium

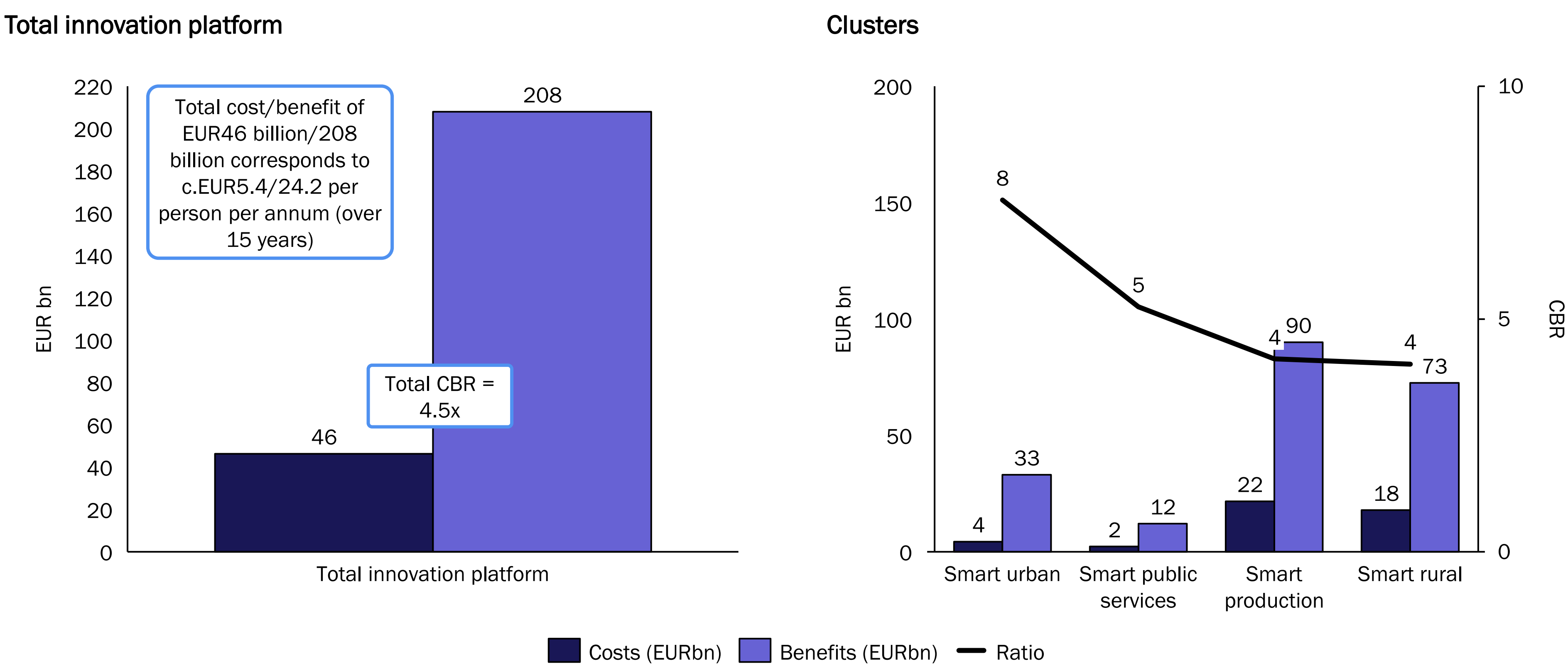
Key: ◑ Could use other wireless solutions ◕ Good ● Very good fit

✔✔✔ Strong alignment with EU policy goals ✔✔ Good alignment ✔ Not highest EU priority

Contents

As a total 'open innovation platform', full 5G networks in Europe can deliver over EUR200 billion benefit, at c.EUR50 billion cost (4.5x ratio additional benefit vs cost)

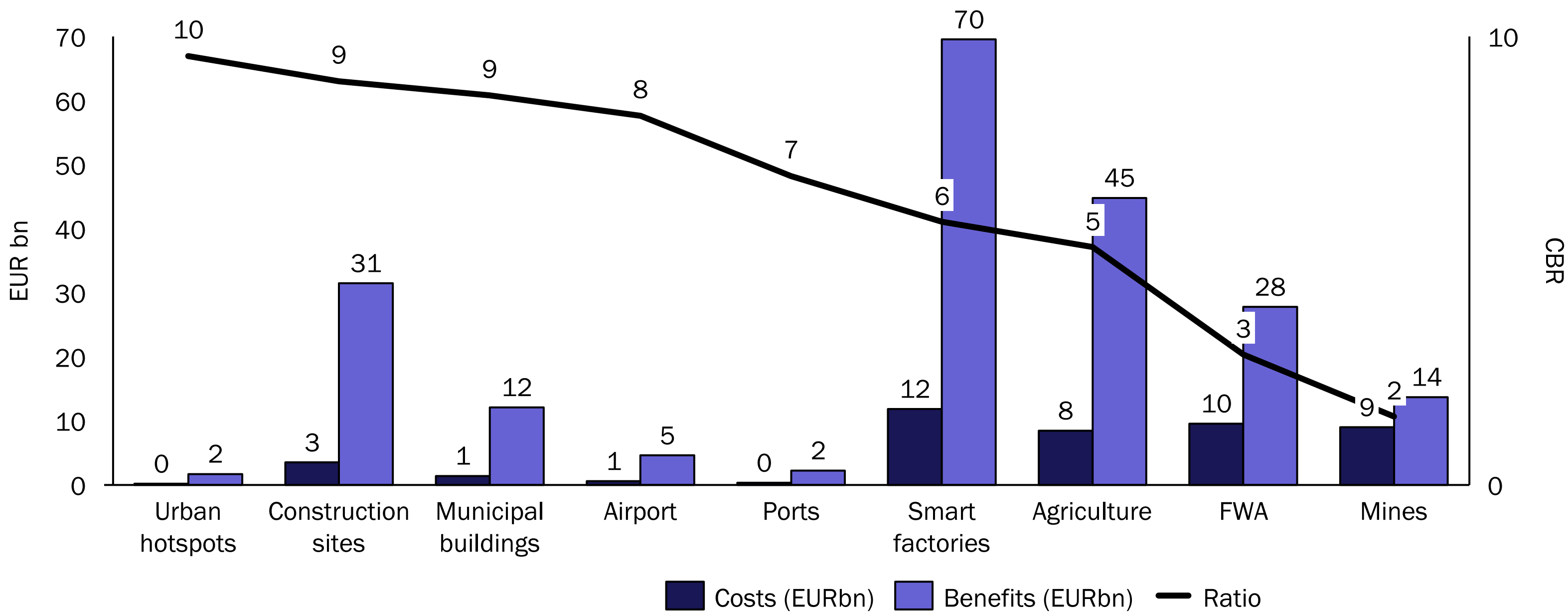
5G upgrade cost, benefit and cost–benefit ratio (CBR), Europe



The benefits and costs shown here are in addition to the benefits leveraged from the initial 5G eMBB network investments in Europe – 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

At the use-case level, the largest economic benefits in terms of European GDP impact are from smart factory, agriculture and 5G FWA (suburban/rural broadband)

Use cases: 5G upgrade cost, benefit and CBR, Europe



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. We have considered the benefits of 5G to these use cases qualitatively in terms of the potential environmental and societal benefits (these include healthcare and hospitals, smart automotive and stadiums). We note consumer benefit will be generated from these use cases, which we have not modelled, but which several other published studies refer to.

- The costs and benefits shown are incremental to costs and benefits gained from initial 5G deployment (i.e. costs and benefits associated with our base case are not shown). "Total" benefit may be (significantly) larger than that shown when also including 5G benefits up to 2025 e.g. Analysys Mason modelling[1] for the 5GAA suggests c.EUR3–4 billion of European benefit from C-V2X (i.e. smart automotive) by 2025, rising to c.EUR20 billion by 2030, not shown here

We have assumed limited synergies between use cases due to localised demand and have not included any common cost from the MBB network (as we assume the MNOs will make 5G MBB available in any event, due to competitive pressure)

Note: FWA is assumed to serve 5–20% of broadband market in each country (guided by current propensity to use FWA services)

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

Many 5G use cases will be delivered by MNOs commercially: where investment is challenging, public subsides can help reduce costs/deployment barriers

5G use case and whether public funding is needed

Use case	Requires public funding
Smart factories	No
Mining	No
Ports	No
Airports	No
Freight and logistics	No
Energy and utilities	No
FWA	Yes[1]
Agriculture	Partly[2]
Construction	No
Urban hotspots including public transport	Partly[3]
Stadiums	No
Smart automotive	Yes
Healthcare and hospitals	Yes
Municipal buildings	Yes
Education	Yes
Tourism	Yes

- Many of the use cases we have considered as part of our full 5G assessment are expected to be deployed and paid for commercially in some environments (i.e. by MNOs on a commercial basis, independently of any EU/government targets)
- In other environments and for some types of deployment where the business case is challenging, use cases that are more likely to require public funding are shown in the table on the left
  - Estimated public funding needs are included in the charts on the next slide

[1] 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).

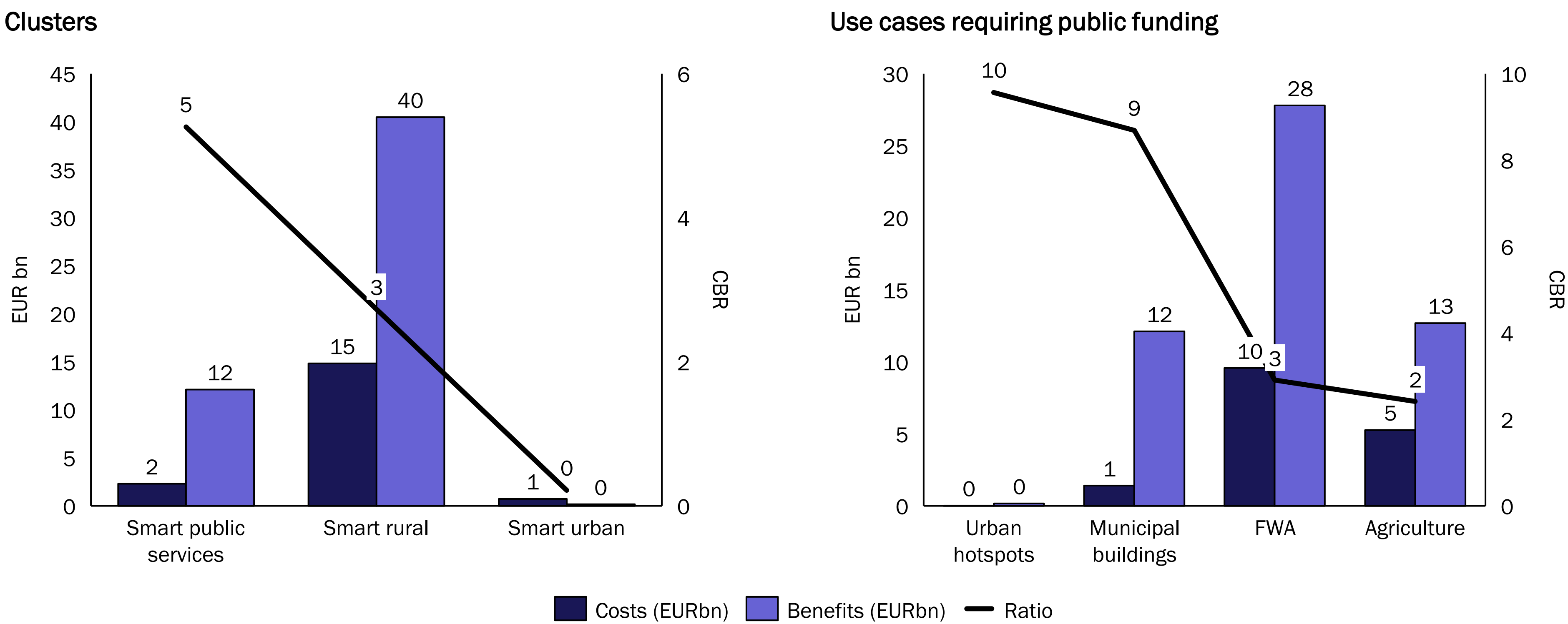
[2] We assume that the agricultural use case would be delivered commercially if the agricultural environment is within the coverage area of our modelled MBB networks. However, we assume that public subsidy would be required for agricultural environments outside the coverage area of our modelled MBB networks.

[3] 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.

Source: Analysys Mason

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 funding

5G upgrade cost, benefit and CBR, Europe – including only those use cases likely to require public funding



- Use cases requiring public funding for which we have modelled economic benefit (healthcare and hospitals, smart automotive) are not included in the right-hand chart above
- it is noted, however, that government funding for 5G infrastructure to support healthcare and hospitals, and autonomous vehicles, will be highly beneficial, based on previous studies

Source: Analysys Mason

Whilst there is a mix of significant benefits from the 5G clusters, the GDP benefit is highest in smart production/logistics and environmental/societal is highest in rural

Summary of economic, social and environmental benefits

Use case	Cluster	Economic benefit (use case)	Economic benefit (cluster)	Social benefit (use case)	Social benefit (cluster)	Environmental benefit (use case)	Environmental benefit (cluster)
Ports	Smart production and logistics	7×	4×	High	Medium	Medium	Medium
Airports		8×		Low		Low	
Mines		1.5×		Medium		Medium	
Smart factories		6×		High		High	
Freight and logistics		N/A (not modelled)		Medium		High	
Energy		N/A (not modelled)		Medium		Medium	
Agriculture	Smart rural	5×	4×	High	High	High	High
FWA		3×		High		Medium	

Colour	Key
Green	High benefit
Orange	Medium benefit
Yellow	Lower benefit

It will be important to consider both the quantitative and qualitative benefits assessment when we are framing the new targets. Across the use cases and clusters there is a mix of high, medium and low benefits to the economy, society and environment.

This means there are many cases where benefits can be realised, which supports the setting of comprehensive targets to explore each of the use cases and/or clusters in more detail

There will also be significant environmental (carbon reduction) benefits from 5G used for real-time connectivity for smart automotive, and in construction sites

Summary of economic, social and environmental benefits

Use case	Cluster	Economic benefit (use case)	Economic benefit (cluster)	Social benefit (use case)	Social benefit (cluster)	Environmental benefit (use case)	Environmental benefit (cluster)
Smart automotive	Smart urban	N/A (not modelled)	8×	Medium	Medium	High	High
Urban hotspot including public transport		10×		Medium		Medium	
Stadiums		N/A (not modelled)		Low		Low	
Construction sites		9×		Medium		High	
Healthcare and hospitals	Smart public services	N/A (not modelled)	5×	Medium	Medium	Low	Medium
Municipal buildings		8×		Medium		Medium	
Education		N/A (not modelled)		Medium		Low	
Tourism		N/A (not modelled)		Medium		Medium	

Legend: High benefit (green); Medium benefit (orange); Lower benefit (yellow)

It will be important to consider both the quantitative and qualitative benefits assessment when we are framing the new targets. Across the use cases and clusters there is a mix of high, medium and low benefits to the economy, society and environment.

This means there are many cases where benefits can be realised, which supports the setting of comprehensive targets to explore each of the use cases and/or clusters in more detail

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In the Smart Production cluster, smart factories are often the largest component of the total benefit (e.g. in Ireland), though in some cases the mining sector is bigger

All countries ranked by benefit ratio: Smart Production

Country	Costs (EUR mn)	Benefits (EUR mn)	Ratio
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
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 the Smart Production 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).

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

Source: Analysys Mason

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

All countries ranked by benefit ratio: Smart Rural

Country	Costs (EUR mn)	Benefits (EUR mn)	Ratio
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
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

Country	Costs (EUR mn)	Benefits (EUR mn)	Ratio
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 Smart Rural cluster has two use cases: agriculture and FWA. The cost is calculated separately per use case for the provision of coverage to

(i) locations within the existing MBB network (traffic is served over the existing MBB network, and thus depends on level of spare capacity)
(ii) 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.

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

Note: Countries with a high ratio (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 (the Netherlands), have a large contribution from the agricultural use case

Source: Analysys Mason

In the Smart Urban cluster, construction sites form the largest cost and benefits component: the cost of coverage is c.4 × higher than that for smart automotive

All countries ranked by benefit ratio: Smart Urban

Country	Costs (EUR mn)	Benefits (EUR mn)	Ratio
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
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).

The construction use case generally has the biggest impact on the CBR of the Smart Urban cluster.

Countries with a high ratio 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).

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

Source: Analysys Mason

Countries which are expected to benefit most from Smart Public Services initiatives are those with a relatively low number of municipal buildings to cover

All countries ranked by benefit ratio: Smart Public Sector

Country	Costs (EUR mn)	Benefits (EUR m)	Ratio
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

Country	Costs (EUR mn)	Benefits (EUR m)	Ratio
Latvia	5	26	5.1
Spain	188	852	4.5
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 healthcare and hospitals. For municipal buildings, the size of the benefit corresponds to public administration sectoral GDP per municipal building.

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

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

Source: Analysys Mason

The new 5G use cases deliver EUR161 billion in net benefit, equivalent to EUR19 per person per annum on average

Analysis of net benefits for Europe

Scope	Total net benefit (EUR bn)	Net benefit per person per annum (EUR)
Total	161	19
Smart Production	68	8
Smart Rural	54	6
Smart Urban	29	3
Smart Public Services	10	1

Analysis of net benefits by country

Country	Total net benefit (EUR mn)	Net benefit per person per annum (EUR)	Country	Total net benefit (EUR mn)	Net benefit per person per annum (EUR)
Austria	8,333	55	Latvia	454	17
Belgium	2,877	15	Lithuania	517	13
Bulgaria	1,694	17	Luxembourg	238	19
Croatia	658	11	Malta	84	8
Cyprus	300	19	Netherlands	6,956	24
Czechia	3,718	22	Norway	2,685	29
Denmark	3,962	40	Poland	10,436	18
Estonia	391	19	Portugal	1,023	6
Finland	5,177	58	Romania	4,919	17
France	15,555	14	Slovakia	771	9
Germany	38,513	29	Slovenia	467	14
Greece	1,658	10	Spain	9,288	12
Hungary	2,295	15	Sweden	4,347	23
Ireland	3,868	45	Switzerland	9,634	64
Italy	7,635	8	UK	13,062	11

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

Source: Analysys Mason

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