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## Conference Paper

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# **The investment gap for the deployment of high-speed broadband in NUTS3 regions**

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## **ABSTRACT**

This paper investigates the high-speed broadband situation in the EU and its prospects. Then it uses a deployment model to estimate the investment required in order to meet the European Gigabit Society (EGS) broadband targets set by the European Commission, aiming at ensuring the availability and take-up of very high capacity fixed and wireless networks, in both urban and rural areas, among households and main socio-economic drivers. The model uses data at the NUTS3 level, which is the most granular level that has data available on the status of broadband deployment, to arrive at a coherent and comparable framework. From the different perspectives on the investment to meet EGS targets, the paper concludes on the need to identify new public and private sources of investment and the case to attract them into the broadband business arena, since expected investment from incumbent and alternative operators would not be enough to fill the gap.

## **1. Background**

High-speed broadband networks have become a key element in the development of our society. According to this relevance, a lot of research has predicted its general impact on the society and the economy (Gruber et al., 2014; Van Der Wee et al., 2015; Mansell et al., 2011) as well as in more specific areas (Analysis Mason & Tech4I2, 2013).

Within this framework, the European Commission adopted on 14 September 2016 a set of initiatives and legislative proposals to place the EU at the forefront of Internet connectivity, as a part of the Commission's strategy on Connectivity for a European Gigabit Society - EGS (European Commission, 2016), which sets a vision of Europe where availability and take-up of very high capacity networks enable the widespread use of products, services and applications in the Digital Single Market.

These initiatives specify an interim target for 2020:

- Intermediate 5G Connectivity to be available as a fully-fledged commercial service in at least one major city in each EU Member State (Target 1, T1).

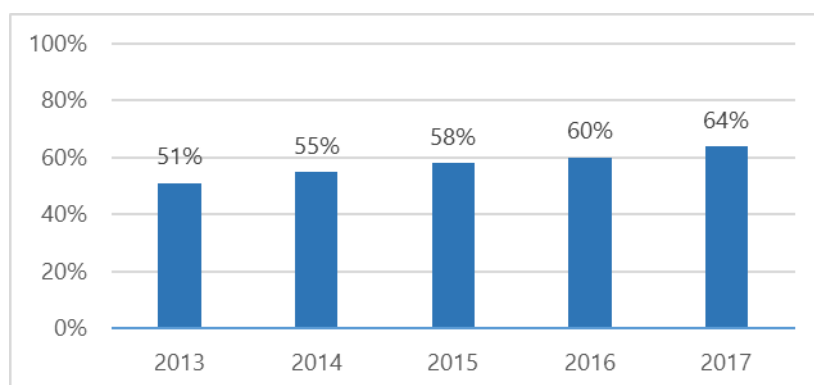
And then sets three main strategic objectives for 2025:

- 5G Connectivity: All urban areas<sup>1</sup> and all major terrestrial transport paths<sup>2</sup> to enjoy uninterrupted 5G coverage (Target 2, T2).
- Gigabit Connectivity: Gigabit connectivity for all main socio-economic drivers such as transport hubs, and main providers of public services<sup>3</sup> as well as digitally intensive enterprises<sup>4</sup> (Target 3, T3).
- Rural Connectivity: All European households, rural or urban, will have access to Internet connectivity offering a downlink of at least 100 Mbps, upgradable to Gigabit speed (Target 4, T4).

In order to reach these targets, the EGS mentions generically that the existing network infrastructure needs to be extended by a smart mix of wireless and wireline technologies requiring large investments in broadband infrastructure.

By mid-2017, 64% of EU households were covered by networks capable of providing downlink speeds at 100 Mbps, just 13 percentage points more than in 2013 (IHS Markit & Point Topic, 2017).

Exhibit 1. Evolution of EU coverage of broadband networks of at least 100 Mbps



Source: (IHS Markit & Point Topic, 2017)

Looking into EU Member States there are up to five countries with coverage beyond 90% as of 2017: Malta, Netherlands, Belgium, Denmark and Portugal. On the contrary, coverage in Finland, France, Poland, Bulgaria, Croatia, Italy and Greece is well below the 50% mark.

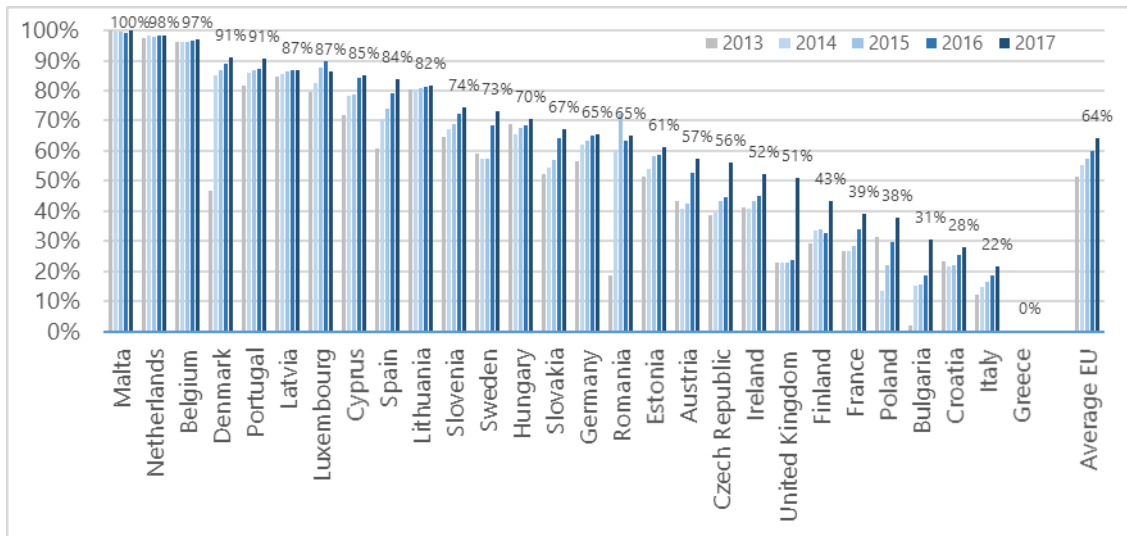
<sup>1</sup> See: [https://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:European\\_cities\\_-\\_the\\_EU-OECD\\_functional\\_urban\\_area\\_definition](https://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:European_cities_-_the_EU-OECD_functional_urban_area_definition)

<sup>2</sup> Motorways, national roads and railways, in line with the definition of Trans-European Transport Networks.

<sup>3</sup> Including primary and secondary schools, train stations, ports and airports, local authority buildings, universities, research centres, doctors' surgeries, hospitals, stadiums, law-related facilities, etc.

<sup>4</sup> Enterprises with a high level of integration of digital technologies.

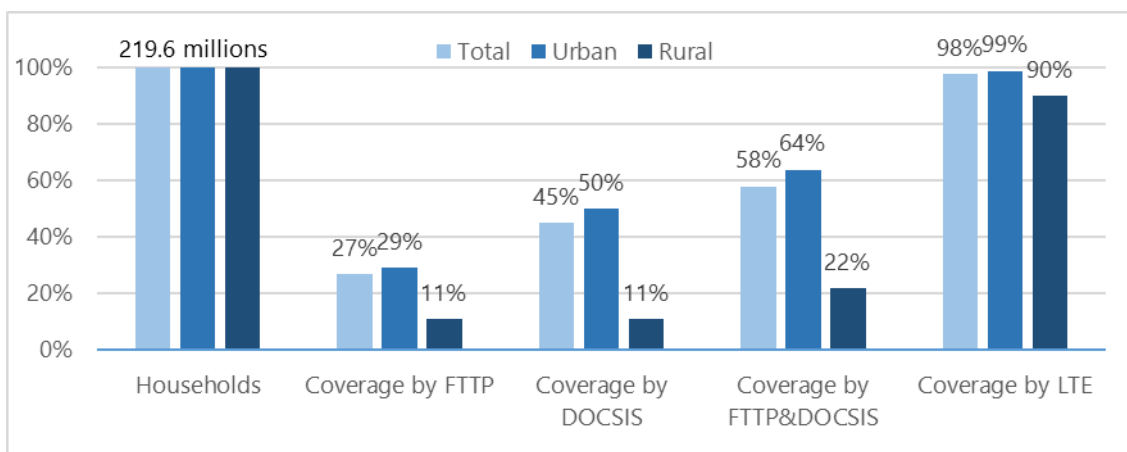
Exhibit 2. Evolution of EU Member States coverage of broadband networks of at least 100 Mbps



Source: (IHS Markit & Point Topic, 2017)

Apart from the substantial differences between EU Member States in general, there is also a very relevant gap between urban and rural areas<sup>5</sup>, in both coverage and take-up. In 2017 the gap from the coverage of technologies able to provide 100 Mbps was 29.4% urban vs. 11.3% rural for FTTP, 50.2% urban vs. 10.8% rural for DOCSIS, and of 99.2% urban vs. 89.9% rural for LTE-A, showcasing the convenience of wireless network deployments for rural areas.

Exhibit 3. EU coverage of broadband networks able to provide at least 100 Mbps in households in urban and rural areas



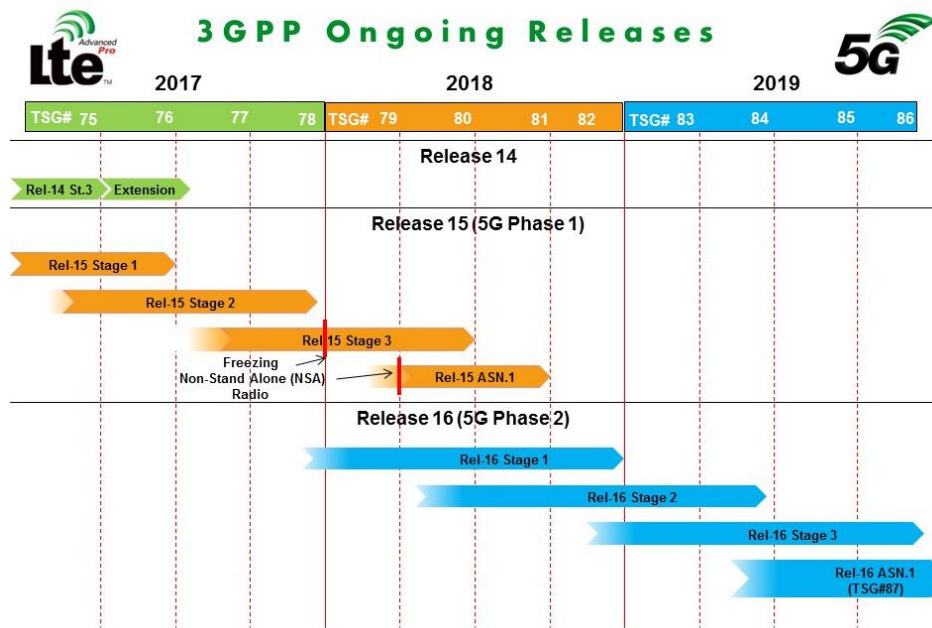
Source: (IHS Markit & Point Topic, 2017)

Regarding 5G, its path is becoming standardized around a technology named 5G New Radio (5G NR), also known as Release 15, which will be eventually replaced with Release 16, in turn expected to last until 2020. Therefore 5G is an evolving technology with first

<sup>5</sup> See definitions of urban and rural areas in the methodology section.

standard equipment -starting with the network deployment and then the user equipment- forecast to be available in late 2018 and early 2019, see Exhibits 4 and 5. In terms of users, Ericsson Mobility Report (2018) predicts that in 2019 there will be a mere 4 million 5G mobile connections worldwide. After that, the situation is expected to change quickly with one billion 5G connections available globally by 2023, with about 150 million in the EU.

Exhibit 4. Wireless communications standardization timeline



Source: 3GPP

Exhibit 5. 5G devices availability



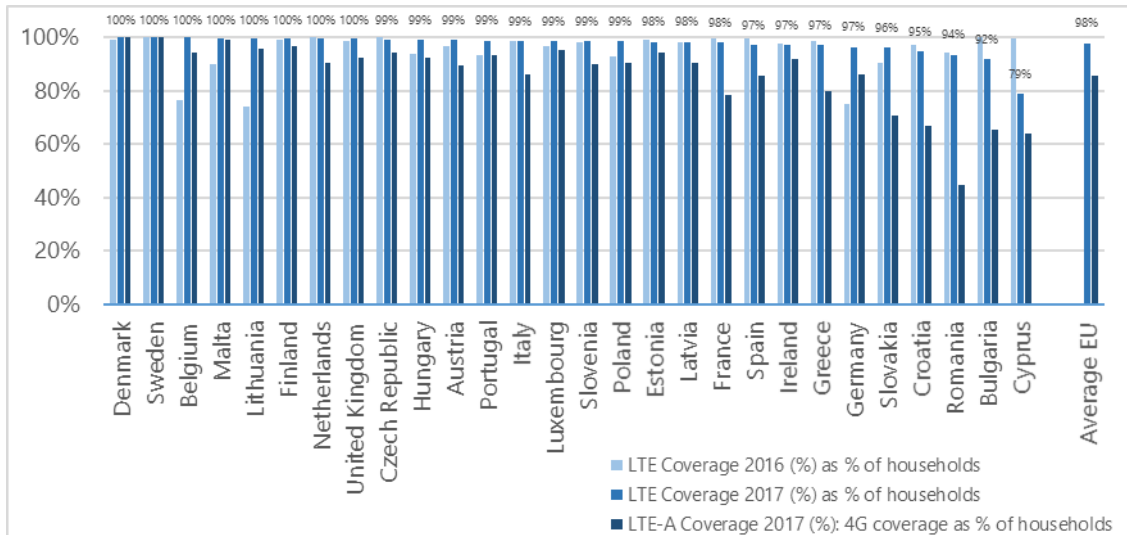
Ericsson Mobility Report June 2018

Source: 3GPP & Ericsson (2018)

Looking from the perspective of the objectives related with the deployment of 5G wireless networks -Intermediate Connectivity (T1) and 5G Connectivity (T2)- a departing

point is the status of deployment of 4G networks, since their footprint will be reused in the upgrade to 5G. In mid-2017 the EU coverage of LTE-A (4G) was 86%, with most of EU Member States beyond the 80% mark with the exceptions of France, Slovakia, Croatia, Bulgaria, Cyprus and Romania.

Exhibit 6. EU Member States coverage of LTE and LTE-A in 2017

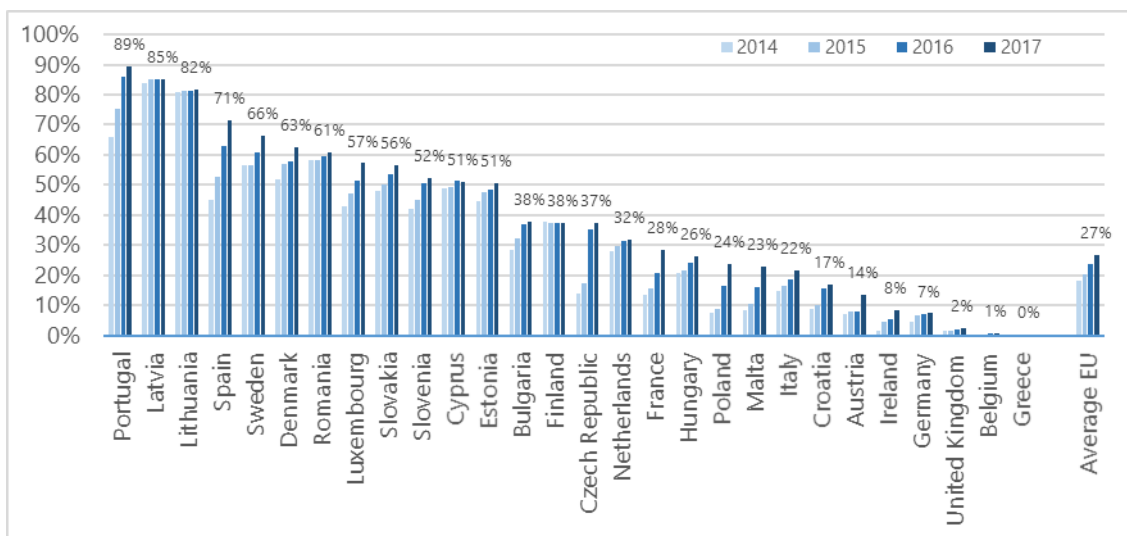


Source: (IHS Markit & Point Topic, 2017)

The departing point of the Gigabit Connectivity (T3) and Rural Connectivity (T4) is the coverage of FTTP and DOCSIS 3.x.

Only three countries have readiness for the upgrade to FTTx of 1 Gbps beyond 80%: Portugal, Latvia and Lithuania. At the same time, there are up to five countries which have coverage of FTTP below the 10% mark: Ireland, Germany, UK, Belgium and Greece.

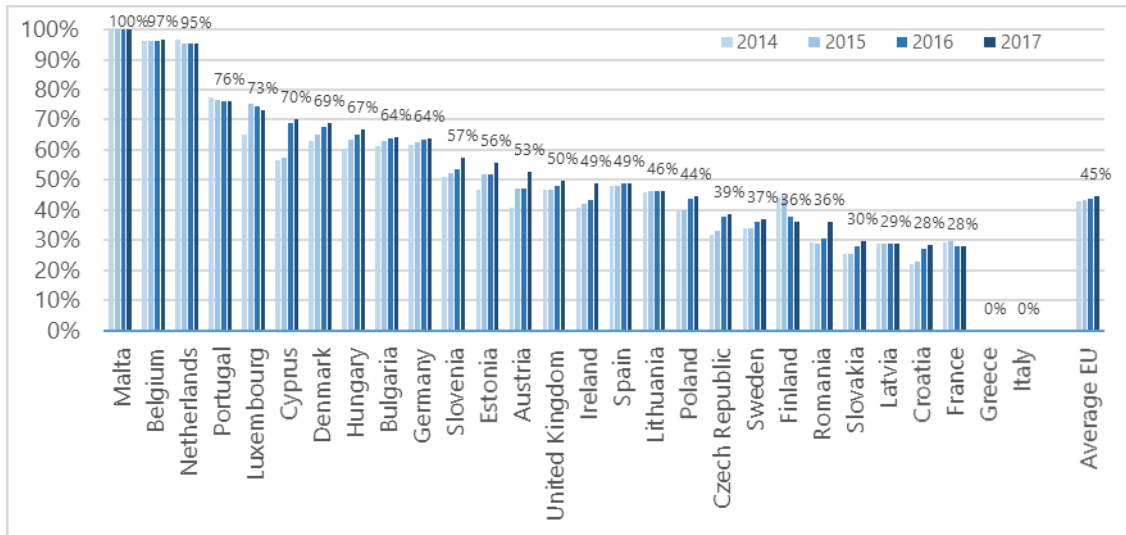
Exhibit 7. EU Member States coverage of FTTP in 2017



Source: (IHS Markit & Point Topic, 2017)

In the case of DOCSIS 3.0, the average coverage in EU is 45% in 2017 and it has remained stable during the last years, highlighting that greenfield deployments no longer use this technology. Member States display rather disparate figures for coverage: Malta, Netherlands and Belgium enjoy beyond 95% coverage while Italy and Greece have negligible coverage.

Exhibit 8. EU Member States coverage of DOCSIS 3.0 2014-2017



Source: (IHS Markit & Point Topic, 2017)

Finally, there is a compilation of on-going initiatives and future commitments of EU Member States operators and public institutions about 1 Gbps broadband networks<sup>6</sup>.

Therefore, many countries in EU seems to be evolving at a slower pace than needed to meet EGS goals. Under this circumstances, different academicians and other players in the industry have focused their research on the deployment of high-speed broadband networks and the investment needed under different scenarios.

In a previous paper (Feijóo et al., 2018) a complete review of the evolution of this line of research during the last years was included, from first attempts focused on modelling deployment scenarios for different technologies, due to the absence of real-life data, to more sophisticated models as new sources of real information appear and granularity of data increases. After that, it concludes on the need to periodically assess the amount of broadband investment required and the feasibility of targets in light of the evolution of technology, funding availability, and policy goals. At the same time, the analysis must cover a diverse range of geographies with different departing points, mix of technologies, and market situation.

This conclusion remains valid and guides this paper, with the final purpose of assessing what exactly is the gap between a realistic prospect of the broadband deployment situation by 2025 and the EGS policy goals, and whether this gap can be addressed before 2025 with business-as-usual deployments or they require additional measures of

<sup>6</sup> See Annex for a detailed compilation by country.

public support. Thus, the aims of this paper are to calculate the 2018 gap, its evolution into the 2025 gap, and the potential impact of different technological options, and to elaborate on some of their consequences.

The following section explains the methodology and the model used to calculate the EGS gap for 2025, including a deeper analysis of the implicit strategic choices. Section 3 shows the resulting gaps for every individual target and for them altogether, considering different scenarios. Section 4 concludes with a view of the expected situation for high-speed broadband in 2025.

## **2. Methodology with further analysis of high-speed broadband situation**

This article can be considered as a follow-up on a previous work focused on estimating the investment required to meet the Digital Agenda for Europe (DAE) broadband targets set by the European Commission in its Europe 2020 strategy (Feijóo et al., 2018). Taking this into consideration, it follows the same methodology as in the aforementioned paper, with little improvements and slight changes required to adapt it to the current analysis.

The assessment of the investment required to complete the Intermediate 5G Connectivity (T1) in 2020, as well as the 5G Connectivity (T2), Gigabit Connectivity (T3) and Rural Connectivity (T4) in 2025, is composed of seven steps: i) geographical framework for the analysis; ii) status of deployment and adoption of technologies relevant to achieve the above targets in each of the regions in the EU, i.e. the 'departing point' of the calculations; iii) level of coverage of high-speed broadband needed to meet the targets, i.e. "the coverage goal", including different scenarios from different possible interpretations; iv) choice of technologies to meet the targets in each country, which also includes different scenarios according with different choices of technologies; v) cost of the deployments needed to meet the targets as of 2018; and vi) estimation of the investment needed, i.e. "the EGS investment gap". An additional step collects prospective deployments from incumbents and alternative operators to calculate the possible public investment gap, i.e. "the amount of additional funding other than operators to achieve the above targets".

### **2.1. Geographical framework**

The geographical framework is based on EU regional data at the NUTS3 level<sup>7</sup>. This is the deepest level for which consistent and reliable socio-economic data is available across the EU<sup>8</sup>. Data are taken from the Eurostat database<sup>9</sup> and refer to the year 2016.

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<sup>7</sup> The Nomenclature of Territorial Units for Statistics (NUTS) is a geocode standard for referencing the subdivisions of countries for statistical purposes. There is a hierarchy of three NUTS levels. The first level is the region or group of regions, the second is generally some type of regional division, and the third is typically a county, district, or department. The NUTS 2016 classification is valid from 1 January 2018 in the EU-28 and lists 104 regions at NUTS1, 281 regions at NUTS2 and 1348 regions at NUTS3 level.

<sup>8</sup> It is worth noting that the 1,348 regions at NUTS3 level (558 of them included in the cohesion priority regions) are rather inhomogeneous regarding size. In member states such as Spain or Finland, the areas are considerably bigger than in countries like Belgium or Germany.

<sup>9</sup> [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo\\_r\\_d3area&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_r_d3area&lang=en)



The basic data consist of population density, number of households<sup>10</sup> and land area. Data on the number of households is transformed into data of number of premises—households and businesses offices—following available EC statistics<sup>11</sup>, as the latter is regarded as more representative of the broadband connectivity gap. From here, each region is classified into five different types according to its average population density: above 500 inhabitants/km<sup>2</sup>, 100 to 500 inh/km<sup>2</sup>, 50 to 100 inh/km<sup>2</sup>, 10 to 50 inh/km<sup>2</sup>, and up to 10 inh/km<sup>2</sup>. Next, each NUTS3 region is assumed to be a combination of five different geotypes: urban, suburban, semirural, rural, and extreme rural. This classification uses LAU2 data (sometimes called NUTS5)<sup>12</sup> from EC (Dijkstra & Poelman, 2014). The use of a double classification into population density and share of geotype offers a deeper understanding of the geographic morphology within a given NUTS3 region and therefore allows estimating the high-speed broadband gap with higher precision, particularly in low-density areas where the gap could be more relevant. This is an agreement with latest rural costing models that highlight the difference in investments required out of town vs. town in rural areas (Rendon Schneir & Xiong, 2016). The aggregated results for the EU using this geographical framework are presented in Table 1 below for population density and in Table 2 for size.

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<sup>10</sup> Households are obtained from Eurostat data, see [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfst\\_hhnhwhc&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfst_hhnhwhc&lang=en). Eurostat does not provide data on geotypes variations. To this respect and considering that rural households tend to have a higher number of persons than urban households, the number of rural households is expected to be higher than real.

<sup>11</sup> Data from Eurostat as of 2015, linearly extrapolated to 2017 figures. Enterprise is defined as the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more locations. An enterprise may be a sole legal unit. See: Eurostat-OECD Manual on Business Demography Statistics: <http://ec.europa.eu/eurostat/documents/3859598/5901585/KS-RA-07-010-EN.PDF/290a71ec-7a71-43be-909b-08ea6bcd521?version=1.0>

<sup>12</sup> A local administrative unit (LAU) is a low-level administrative division of a country that is typically ranked below a province, county, district, or department. In the EU, it belongs to the NUTS classification where two levels are defined, LAU1 and LAU2, which were previously called NUTS4 and NUTS5. LAU2 typically refers to municipalities.

Table 1. Distribution of NUTS3 regions according to premises and geotype

Pop. Density	Number of NUTS3 regions	Pop (m)	Number of premises (m)	Urban geotype (%)	Suburban geotype (%)	Semi-rural geotype (%)	Rural geotype (%)	Extreme rural geotype (%)
Up to 10 inh/km2	17	2.58	1.33	13.6%	37.6%	5.3%	14.7%	28.8%
10 to 50 inh/km2	179	34.77	16.84	17.8%	34.9%	11.9%	28.4%	7.0%
50 to 100 inh/km2	296	92.62	42.59	20.6%	32.4%	25.5%	20.7%	0.8%
100 to 500 inh/km2	563	226.67	109.54	28.5%	45.4%	21.8%	4.1%	0.2%
Above 500 inh/km2	293	155.89	75.54	78.8%	18.5%	2.3%	0.3%	0.1%
Total	1,348	512.53	248.84	42%	34%	16%	8%	1%

Source: Own calculations from Eurostat data

Table 1 shows how there is a correspondence between population density and the usual descriptors of urban, suburban, and rural geotypes, and in terms of premises in the EU-28 there is a 25% share belonging to rural areas on average. But it also points to the fact that within a given region there is a combination of geotypes and that an oversimplification directly linking population density and geotypes can be considerably misleading. Even areas generally regarded as suburban, with a relatively high population density, keep within them about a 25% share of rural areas. On the contrary, very rural and remote areas have a considerable share of urbanisation, 14% and 18%, respectively, which is a relevant difference for broadband deployment calculations.

Table 2. Distribution of NUTS3 regions according to area and geotype

Pop. Density	Number of NUTS3 regions	Pop (m)	Area (km2)	Urban geotype (%)	Suburban geotype (%)	Semi-rural geotype (%)	Rural geotype (%)	Extreme rural geotype (%)
Up to 10 inh/km2	17	2.58	588,028	1.6%	14.9%	1.1%	6.0%	76.5%
10 to 50 inh/km2	179	34.77	1,207,671	3.2%	13.0%	4.5%	41.1%	38.1%
50 to 100 inh/km2	296	92.62	1,267,968	2.2%	13.7%	22.4%	51.4%	10.4%
100 to 500 inh/km2	563	226.67	1,216,452	5.7%	28.3%	37.3%	24.5%	4.2%
Above 500 inh/km2	293	155.89	126,256	41.0%	33.9%	14.7%	7.5%	3.0%
Total	1,348	512.53	4,406,375	4%	18%	19%	34%	25%

Source: Own calculations from Eurostat data

Table 2 shows the disparity between population density and size, with the land area of rural geotypes (semi-rural, rural and extreme-rural) in the EU-28 accounting for 78% share, and urban and suburban geotypes just reaching 22% of the total size but accounting for 75% of the population. This table also displays that within a given region there is a combination of geotypes and even areas generally regarded as suburban, with a relatively high population density, keep within them about a 65% of their size as rural geotype areas.

## 2.2. Status of high-speed broadband

The other basic set of parameters required at the NUTS3 level are those related to existing high-speed broadband deployment in 2017: the coverage in terms of population at 30 Mbps, 100 Mbps and 1 Gbps levels, as well as the adoption at 100 Mbps level.

Coverage at 30 Mbps and above equals the maximum footprint of FTTx, VDSL or other advanced DSL technologies, and DOCSIS 3.x<sup>13</sup>. Coverage and adoption at 100 Mbps have been made equal to the deployment of FTTH, FTTB, FTTC only when used in combination with advanced DSL techniques<sup>14</sup>, and DOCSIS 3.x<sup>15</sup>. LTE-A is considered in extreme-rural areas as a potential candidate for 100 Mbps, and LTE as a technology is suitable to provide 30 Mbps in rural areas<sup>16</sup>. Regarding 1 Gbps, technologies considered as a departing point are FTTH, FTTB, and DOCSIS 3.1 or superior. Regarding 5G, the study considers that the departing point is LTE-A, this is, all the LTE-A sites will be upgraded to 5G in addition to the deployment of new cells.

The data regarding coverage and adoption were obtained from the European Commission (Digital Agenda – Digital Economy and Society Index databases) for 2012 to 2018. At the NUTS3 level, coverage data were obtained from IHS Markit & Point Topic study for the EC that supplies data for the year 2017 (IHS Markit & Point Topic,

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<sup>13</sup> According to the EC report on broadband (IHS Markit & Point Topic, 2017), the category of "coverage by broadband network/s capable of realistically achieving actual download speeds of at least 30 Mbps encompassed VDSL, FTTP, and DOCSIS 3.0 cable broadband access technologies. However, as not all connections utilizing these technologies can achieve 30 Mbps and higher actual download speeds (for example, VDSL connections with distance from the exchange point higher than 500m see radical decrease in actual speeds), respondents were asked to exclude those connections which did not meet the criteria from their answers".

<sup>14</sup> We refer to technologies that fully or partially use existing copper wire legacy infrastructures. Some of the technologies include G.fast over copper and bonding and vectoring techniques. Deployments show that these technologies could reach up to hundreds of Mbps at distances up to 1 Km, see Lemstra (2016) for an account of its implications for the industry. Currently within the EU Member States only the UK seems to bet on this technology. According to Point Topic: "BT and Swisscom are leading G.fast deployment in Europe. In the UK, BT has committed to covering 10 million premises by 2020, although only 93,000 live as of early 2018. The operator uses FTTC (fibre to the cabinet) and offers download speeds of up to 330Mbps. Swisscom has deployed FTTS (fibre to the street) based G.fast services to 70,000 premises, bringing fibre closer to the customer. As a result, the Swiss incumbent offers maximum speeds of up to 500Mbps. Meanwhile German alternative operator M-net has rolled out G.fast in two districts of Munich. Like BT, it offers maximum theoretical download speeds of up to 300Mbps." See <http://point-topic.com/g-fast-broadband-premises-3m/>

<sup>15</sup> According to the EC report on broadband (IHS Markit & Point Topic, 2017), the category of "coverage by broadband network/s capable of realistically achieving actual download speeds of at least 100 Mbps encompassed FTTP and DOCSIS 3.0 cable broadband access technologies. In cases where vectoring is applied to VDSL2 technology and speeds reach 100 Mbps and higher download speeds, VDSL with vectoring was asked to be included in this category. However, as not all connections utilizing these technologies can achieve 100 Mbps actual download speeds (for example, in the case of FTTB – fibre-to-the-building – connections included in the FTTP category in-building wiring can pose significant constraints on achievable end-user broadband speeds), respondents were asked to exclude those connections from their answers.

<sup>16</sup> As this is a prospective exercise, technologies such as satellite or fixed wireless over microwave links have been excluded from the analysis.

2017). When needed, data at NUTS3 level were adjusted using the population density of the area and ensuring coherence with national data.

Table 3 below summarises the results and displays the status of deployment of the main technologies relevant for EGS targets. There are two thresholds where fixed networks — both fibre and cable — drop dramatically: from urban into suburban, and from suburban into semirural geotypes. Wireless networks have almost full coverage in urban and suburban geotypes and as of 2017 drop only at rural and extreme-rural geotypes. It is also worth noting the leading role of cable-based technologies in some key stages of ultrafast broadband development.

Table 3. Deployment of high-speed broadband technologies (% premises) by geotype (2017)

Geotype	FTTH/B	DOCSIS	LTE-A
Urban	54.2%	79.0%	99.7%
Suburban	15.7%	34.8%	98.5%
Semi-rural	3.0%	4.8%	63.6%
Rural	2.2%	0.0%	17.0%
Extreme rural	0.2%	0.0%	44.0%

Source: Own estimation

### 2.3. High-speed broadband coverage targets

The next step is the specification of the high-speed broadband coverage required to meet the EGS objectives.

The Intermediate 5G Connectivity objective (T1) calls for 5G to be available in at least one major city in each Member State. This study interpretation equals one major city with the NUTS3 regions of the capital city of each Member State.

The 5G Connectivity objective (T2) aims at all urban areas and all major terrestrial paths with uninterrupted 5G coverage. Motorways and national roads data were obtained from Eurostat. The maximum length among the E-type of roads, motorways and TEN-T networks was selected for each country. Railways data were obtained from Eurostat and World Bank. They were distributed at country level proportionally to the land size of each geotype within each NUTS3 region.

Table 4. National roads and railways (km) in the EU (2017)

Country	Roads (km)	Railways (km)	Country	Roads (km)	Railways (km)
Austria	2,248	5,491	Italy	8,809	16,788
Belgium	2,026	3,602	Latvia	202	1,860
Bulgaria	2,953	4,029	Lithuania	1,652	1,911
Croatia	2,251	2,604	Luxembourg	161	275
Cyprus	272	0	Malta	109	0
Czech Republic	2,636	9,564	Netherlands	2,756	3,058
Denmark	1,554	2,131	Poland	5,500	19,132
Estonia	1,350	1,161	Portugal	3,065	2,546
Finland	5,229	5,926	Romania	6,200	10,774
France	12,797	28,364	Slovakia	1,524	3,206
Germany	12,996	38,466	Slovenia	773	1,209
Greece	4,831	2,240	Spain	15,444	16,167
Hungary	2,348	7,811	Sweden	6,745	10,882
Ireland	2,258	1,931	United Kingdom	6,926	16,253

Source: Own estimations from Eurostat and World Bank

The Gigabit Connectivity objective (T3) expects to provide 1 Gbps connectivity for all main socio-economic institutions and digitally intensive enterprises. While there is a list of suggested institutions in the EGS document, this study interpretation for digitally intensive enterprises is simply that in 2025 all companies should have become digitally intensive in order to stay competitive and therefore require connectivity. Therefore, there will be three scenarios for this objective depending on the number of companies and institutions: T3.1 "all enterprises" which includes 28.5m of companies and institutions<sup>17</sup>; T3.2 "5m enterprises and institutions" and T3.3 "1m enterprises and institutions"<sup>18</sup>. They are assumed to be evenly distributed across geotypes. In addition, the take-up of digital enterprises is assumed to be 100%.

Finally, the Rural Connectivity objective (T4) states that all European households, rural or urban, will have access to Internet connectivity offering a downlink of at least 100 Mbps, upgradable to Gigabit speed. To this respect, there are two different scenarios identical for all the EU Member States: T4.1 "extreme-rural wireless" and T4.2 "rural wireless".

## 2.4. Choice of high-speed broadband technologies

It is not only a matter of a coverage goal but also the key technologies to provide such coverage. In the case of Gigabit Connectivity (T3) and Rural Connectivity (T4) objectives,

<sup>17</sup> 27.5m of companies and 1m institutions (local authority buildings, hospitals, schools, libraries, museums, sites of cultural interest, post offices and police stations)

<sup>18</sup> This is rather similar to Analysis Mason Scenario A for Gigabit connectivity consisting of 486,000 SMEs (50-249 employees) + 210,000 local authority buildings + 110,000 hospitals + 210,000 primary and secondary schools (Analysis Mason, 2016).

the assumptions about the technologies deployed are country-specific and depend on the preferred route for rolling out broadband coverage by incumbent and alternative providers in each country. In some countries there has been a clear preference for using FTTB/C technologies. In other countries there has been a clear preference for FTTH technologies. There are even some cases in which the choice of technology depends on the geotype. Table 5 summarises the situation in the EU as of 2018.

Table 5. Technology choices for the deployment of FTTx in the EU (2018)

Dominant technology	Countries
FTTH	Croatia, Cyprus, Estonia, France, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden
FTTB/C	Austria, Belgium, Bulgaria, Czech Republic, Denmark, Germany, Greece, Italy
FTTH in urban geotypes and FTTB/C in the rest	Finland, Netherlands, Poland, United Kingdom

Source: Own estimations from publicly available information at country level

In addition, there is the comparative situation of cable vs. fibre deployment. Table 6 summarizes the dominance of each type of technology across the EU. This information is the departing point for the cost model to consider the portion of existing network technologies (FTTx, DOCSIS) that can be upgraded to reach the corresponding objectives at a lower cost than new full deployments.

Table 6. Fibre vs. cable deployments in the EU (2018)

		Fibre- FTTP			
		<10%	10-25%	25-50%	>50%
Cable - DOCSIS	<10%	Greece**	Italy***		
	10-25%				
	25-50%	Ireland, United Kingdom**	Croatia, Poland	Czech Republic**, Finland, France	Latvia, Lithuania, Romania, Slovakia, Spain, Sweden
	>50%	Belgium, Germany*	Austria*, Malta	Bulgaria, Hungary, Netherlands	Cyprus, Denmark, Estonia, Luxembourg, Portugal, Slovenia

\* FTTC between 10 and 25%, \*\* FTTC between 25 and 50%, \*\*\* FTTC more than 50%

Source: Own estimations from publicly available information at country level

Departing from this country-by-country situation for FTTx and DOCSIS deployments, then additional assumptions are considered for some objectives to depict the corresponding technology mix for each Target presented in Table 8.

Table 7. Scenarios for the deployment of high-speed broadband technologies<sup>19</sup>

Geotype	T1 (Intermediate) / T2 (5G)		T3 (Gigabit)	T4 (Rural 1 Gbps)	
	T1.1/T2.1 Guaranteed quality	T1.2/T2.2 Nominal quality	T3.1/2/3 No. of digital intensive companies	T4.1 Extreme-rural wireless	T4.2 Rural wireless
Urban	5G	5G	FTTH	FTTH	FTTH
Suburban		5G	FTTH	FTTH	FTTH
Semi-rural		(just for roads and railways)	FTTH	FTTH	5G
Rural			FTTH	FTTH	5G
Extreme rural			FTTH	5G	5G

Source: Own model

For Intermediate Connectivity (T1) and 5G Connectivity (T2), there are two scenarios depending on 5G quality: T1.1 / T1.1 “guaranteed quality” and T2.2 / T2.2 “nominal quality”.

In the case of Gigabit Connectivity (T3), the assumption consists of FTTH prepared for 1 Gbps or DOCSIS3.1<sup>20</sup> for all countries and geotypes. The scenarios of T3 depend on the number of digitally intensive companies as explained in the previous sub-section. The T3 scenarios are presented with and without update to DOCSIS3.1.

For Rural Connectivity (T4), there are two different scenarios identical for all the EU Member States: T4.1 “extreme-rural wireless” where 5G is only considered in the extreme-rural geotype whereas the rest of geotypes use FTTH prepared for 1 Gbps connectivity or DOCSIS3.1; and T4.2 “rural wireless” where 5G is extended to the three rural geotypes. For T4 it has also been assumed that the currently installed base of FTTH is not yet FTTH-capable-of-1Gbps, and therefore it should be updated. The T4 scenarios are presented with and without update to DOCSIS3.1.

Finally, the estimations are presented in the Results and Discussion section for each objective in isolation but also in three different aggregated combinations of technologies and assumptions, named as follows:

- Baseline (highlighted in Table 8): T1.2 “nominal quality”, T2.2 “nominal quality”, T3.1 “all enterprises”, T4.1 “extreme-rural wireless”, including DOCSIS update.
- Maximun (Max): T1.1 “guaranteed quality”, T2.1 “guaranteed quality”, T3.1 “all enterprises”, T4.1 “extreme-rural wireless”, without DOCSIS update.

<sup>19</sup> In the case of T3 and T4, FTTH prepared for 1 Gbps or DOCSIS3.1.

<sup>20</sup> Several sources highlight the possibility of DOCSIS3.1 being able to provide 1 Gbps (Taga & Peres, 2018). In fact some countries such as Germany have started the commercialization of this technology, see for instance <https://www.vodafone.com/content/index/media/vodafone-group-releases/2017/vodafone-germany-gigabit-investment-plan.html>

- Minimum (Min): T1.2 “nominal quality”, T2.2 “nominal quality”, T3.3 “1m enterprises”, T4.2 “rural wireless”, including DOCSIS update.

## 2.5. Deployment costs<sup>21</sup>

The deployment costs for each technology are based on relevant reports and academic papers on NGA deployment and depend on technology and geotype. They include previous studies on NGN deployment from different institutions and organisations (EIB, 2011; FCC, 2010; FTTHCE, 2012; OECD, 2009), forecasts regarding the evolution of high-speed broadband networks from main market analysts (Analysis Mason & Tech4I2, 2013; IDATE, 2013; Point Topic, 2013), and available academic literature on the subject (C. Feijóo, Ramos, Armuña, Arenal, & Gómez-Barroso, 2018; Claudio Feijóo & Gómez-Barroso, 2013; Han, Sung, & Zander, 2013; Oughton & Frias, 2016; Ovando, Pérez, & Moral, 2015; Tselekounis & Maniadakis, 2012), and industry referencies (5G-PPP Automotive Working Group, 2018; Vodafone Germany, 2017)<sup>22</sup>.

The costs have been combined in a weighted average for each of the technologies and geotypes and adapted for each country<sup>23</sup>. For this, it has been considered that deployment requires on average 70% of civil works, and this cost has been adapted into the labour force in each member state from the Eurostat database 2017<sup>24</sup>.

In a last step a factor for preparedness of new broadband deployments at country level has been included. This factor considers geographic elements -how mountainous is the country-, sociodemographic elements -dominant type of buildings-, and local and national regulation elements -sharing infrastructure precedents and laws, municipal licences and permissions.

Each element is weighted according to its perceived influence<sup>25</sup> being the result per country a simple sum of the three components considered. In consequence, the factor impacts on deployment costs between +30% to -30%. According to FTTH Council the savings opportunities linked to the measures proposed in the Directive on Broadband Cost Reduction such as reuse of passive infrastructures and infrastructure sharing amount to 12%, with other estimates as high as 40% (FTTHCE, 2017).

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<sup>21</sup> Note that this study only considers capital investments (capex) at 2018 prices. Therefore, operating expenses (opex), maintenance of assets, inflation, decrease of equipment prices due to possible increases of technology efficiency and WACC are not included in the model.

<sup>22</sup> Figures for the update from current FTTH to 1 Gbps FTTH come from discussions with main European operators.

<sup>23</sup> The deployment costs have been calculated using the procedure described in the following. First data on deployment costs have been compiled from the literature described in the main text. Second all the prices have been transformed to 2018 using the corresponding inflation index. Third, deployment costs for each type of technology have been combined in a weighted average using weight “5” for specific projects / local / municipal deployment costs, weight “4” for NUTS3 regional deployment costs, weight “3” for NUTS2 regional deployment costs, weight “2” for country deployment costs and weight “1” for EU-wide deployment costs. These weights try to capture the reliability of costing data, from more reliable (specific deployments) to less reliable (EU general deployments). This heuristic procedure has also the advantage of incorporating new data as soon as they are available.

<sup>24</sup> See labour cost levels by NACE Rev. 2 activity at [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lc\\_lci\\_lev&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lc_lci_lev&lang=en)

<sup>25</sup> Negative impact: -10%; neutral impact: 0%; positive impact: +10%.



Table 8. Network preparedness factor in the EU (2017)<sup>26,27,28</sup>

Country	Geographic landscape factor	Housing factor	National / local regulation factor	Preparedness factor combined
Austria	10%	0%	-10%	0%
Belgium	-10%	0%	-10%	-20%
Bulgaria	10%	0%	10%	20%
Croatia	0%	0%	10%	10%
Cyprus	0%	0%	10%	10%
Czech Republic	0%	-10%	0%	-10%
Denmark	0%	0%	-10%	-10%
Estonia	-10%	-10%	0%	-20%
Finland	10%	0%	-10%	0%
France	0%	0%	0%	0%
Germany	-10%	-10%	-10%	-30%
Greece	10%	-10%	10%	10%
Hungary	-10%	0%	10%	0%
Ireland	-10%	10%	-10%	-10%
Italy	10%	-10%	10%	10%
Latvia	0%	-10%	0%	-10%
Lithuania	0%	-10%	0%	-10%
Luxembourg	-10%	0%	-10%	-20%
Malta	0%	-10%	0%	-10%
Netherlands	0%	10%	-10%	0%
Poland	-10%	0%	10%	0%
Portugal	0%	0%	0%	0%
Romania	0%	0%	10%	10%
Slovakia	10%	-10%	10%	10%
Slovenia	10%	0%	10%	20%
Spain	10%	-10%	10%	10%
Sweden	10%	0%	-10%	0%
United Kingdom	0%	10%	-10%	0%

Source: Own estimations from Nordregio (2004), Eurostat and WEF

Costs display the capital expenditure of network rollout to pass subscribers' premises and do not include elements from the core, backbone, transport, or aggregation

<sup>26</sup> The geographic landscape factor is based on the percentage of country area covered by mountainous municipalities.

<sup>27</sup> The housing socio-demographic factor is based on the distribution of population by dwelling type from Eurostat - Distribution of population by degree of urbanisation, dwelling type and income group – 2016, see [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc\\_lvho01&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_lvho01&lang=en)

<sup>28</sup> The national/local regulation factor is based on data from Pillar 1 (Political and regulatory environment) of the Network Readiness Index – 2016, see <http://reports.weforum.org/global-information-technology-report-2016/networked-readiness-index/>

networks and CPEs. Costs are expressed in euros at 2018 prices. Table 9 below summarises average EU deployment costs.

Note that where it was possible to reuse existing deployments as it happens in the cases of FTTx to FTTH, from FTTH to FTTH prepared for 1 Gbps, from DOCSIS3.0 to DOCSIS3.1 and from 4G to 5G, the upgrade cost has been preferred to the full deployment cost.

In the case of 5G Connectivity (T5) for roads and railways, it has been used the capex per km averaged for all geotypes and the cost of railways and road coverage is assumed to be independent of -therefore, additional to- the cost of urban geotype coverage. Road capex includes the equipment needed for automated driving based on 5G. Railways deployment of fibre is assumed for 75% of their length, while fibre deployment along roads is assumed for 50% of their length.

Table 9. EU average deployment costs (€ per premise passed)<sup>29</sup>

	Urban	Suburban	Semi-rural	Rural	Extreme rural
FTTH	561	1,376	2,032	2,633	6,783
FTTB	416	838	1,375	2,134	2,467
FTTC	283	476	816	1,380	1,549
Upgrade to FTTH from FTTB	188	643	813	870	4,836
Upgrade to FTTH from FTTC	321	1,005	1,372	1,455	5,754
Upgrade to FTTH prepared for 1 Gbps from 100 Mbps FTTH	112	275	406	527	1,357
Upgrade to DOCSIS 3.1 from DOCSIS 3.0	80	196	290	375	967
LTE-A guaranteed quality	374	478	582	912	1,163
LTE-A nominal quality	59	104	207	641	817
5G guaranteed quality	712	930	1,131	1,692	7,088
5G nominal quality	444	565	687	871	1,330
5G for railways nominal quality (€/km)			35,000		
5G for railways guaranteed quality (€/km)			55,000		
5G for roads nominal quality (€/km)			95,000		
5G for roads guaranteed quality (€/km)			115,000		

Source: Own calculations from meta-analysis of relevant literature, see above

<sup>29</sup> FTTH-GPON has been preferred for cost calculations to FTTH P2P due to its prevalence in the EU. In addition, the cost for 5G spectrum is not considered. The costs for 5G in roads and railways considered (in €/km) is common for all geotypes.

## **Deployments from operators**

Based on previous years' record of investment, it is expected that operators will fund 10.4 b€ per year in fixed high-speed broadband networks (C. Feijóo et al., 2018) and 22 b€ per year in wireless networks (GSMA, 2017).

The fixed network figure is slightly higher than previous estimates of 9.6 b€ of operator investment per year (Analysis Mason & Tech4I2, 2013) and lower than BCG estimations at 14.1 b€ per year (Bock, Soos, Wilms, & Mohan, 2015). Note that the operators are expected to invest 83.2 b€ in high-speed fixed networks, but about one-third of the operators' investment is not conducive to decrease the fixed high-speed broadband gap for EGS calculation, as it takes place in areas where there are already investments from the same or a similar type of operators in alternative technologies, such as FTTH deployments in areas with DOCSIS or FTTC-VDSL coverage. Therefore only 55.5 b€ will be accounted for the EGS investment gap calculation. A previous study from Analysis Mason (2016) basically agree on the amount of high-speed fixed network investment from operators, estimated in their study at 81.2 b€.

In the case of wireless technologies, according to GSMA: "There is little guidance on 5G operator mobile capex [...] ultimately, it will depend on a number of factors including the model selected for network deployments, the targeted network coverage, the range of spectrum bands in use, and the availability of fibre infrastructure and nationwide LTE networks. It is also reasonable to assume a gradual rollout path; indications from the Chinese mobile operators are that 5G investment will follow a more gradual route and over a longer period than 4G, roughly seven years, from 2018 to 2025. Japanese operators claim that the deployment of 5G will not lead to any significant spike in capex". Therefore, using annual average figures for EU operators' capex on wireless networks in the period 2018 to 2020 leads to a figure of 22 b€ per year (GSMA, 2017), sufficient to cover deployments in urban areas and transport paths -estimated at 7.7 b€ per year for 5G networks in urban areas and main transport paths.

Note that the total investment of operators per year of 32.4 b€ is lower than EC estimates of 36 b€ per year (European Commission, 2016), and in addition in this study it is highlighted that not all of these investments are relevant for the EGS targets.

## **Estimation of the investment gap**

There are two fundamental assumptions for the estimation of the investment gap: i) all new deployments are considered to follow market logic which implies that the more densely populated areas are covered first, and ii) all new fixed-network deployments are based on fibre technologies.

In addition, the model considers fixed technology overlaps, as market developments show that fixed technologies compete in the same areas. This is the case, for example, of incremental fibre-based rollout promoted by incumbents that target the same areas in which cable providers operate with DOCSIS3.x solutions. As mentioned in all country cases, only fibre-based technologies are considered for new rollout; therefore, no further cable deployment from the existing coverage footprint in 2017 is forecasted.

This is consistent with the market logic of incumbents that reuse technologies where possible but invest in new infrastructures able to provide the highest flexibility and features for broadband services provision, a result already reported in the critical review of Cambini & Jiang (2009).

Results are presented for each objective in isolation but also aggregated according to the following approach in order to avoid overlaps among objectives. The analysis starts from the deployment situation of high-speed broadband as of 2017 to estimate the broadband investments from 2018 (“the 2018 EGS investment gaps”). Intermediate 5G Connectivity (T1) is first considered. Then, total 5G Connectivity (T2) is added, taking into account that T1 is mostly overridden except for the non-urban geotypes contained within the capital city regions of each Member State. Addition of T4 and then T3 helps to complete the scene, but with two additional considerations that require certain adjustments to fine-tune the model: part of T3 is already covered by T4 and T3 considers FTTH in the extreme-rural geotype.

A final remark/disclaimer on the methodology from the authors’ perspective is that its goal is not to provide the ultimate figures for the EGS investment gaps but to provide a rational and coherent framework to address the order of magnitude of the gap and some main insights into its nature, and to test the impact of different alternative scenarios. The error margin of the assessment of the investment gap derives from three main sources: lack of granularity of data on the coverage and adoption of technologies, projections on operators’ investments, and projections on deployment costs and revenues. The authors’ intention was to collect the most updated information in those three areas. In any case, the figures in this study must be interpreted with great caution and only within the framework of the assumptions made.

### 3. Results and discussion

This section displays the results obtained from applying the methodology above to NUTS3 regions in Europe, presenting each target individually and their combination to fulfil EGS objectives in the corresponding subsections. Each analysis considers three estimations scenarios (baseline, maximum, minimum)<sup>30</sup> according to the mix of technologies and assumptions presented previously<sup>31</sup>. In addition, different comparisons and some remarks on the NUTS3 level results across EU close the section.

The following tables display a summary of the results for the EU-28 and EU-27 respectively, highlighting the results for the baseline estimations and the aggregate amount to achieve EGS objectives.

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<sup>30</sup> Baseline: T1.2 “nominal quality”, T2.2 “nominal quality”, T3.1 “all enterprises”, T4.1 “extreme-rural wireless”, including DOCSIS update to 1Gbps.

Maximum: T1.1 “guaranteed quality”, T2.1 “guaranteed quality”, T3.1 “all enterprises”, T4.1 “extreme-rural wireless”, without DOCSIS update to 1Gbps.

Minimum: T1.2 “nominal quality”, T2.2 “nominal quality”, T3.3 “1m enterprises”, T4.2 “rural wireless”, including DOCSIS update to 1Gbps.

<sup>31</sup> As presented in the Methodology section, data on the number of households is transformed into number of premises — households and businesses offices — following available EC statistics, as the latter is regarded as more representative of the broadband connectivity investments.

Table 10. Summary of EGS investment needs (b€) in the EU-28

EU-28	Baseline	Max	Min
T1 (intermediate connectivity – major city)	14.5	23.6	14.5
T2A (5G connectivity – urban areas)	44.6	71.4	44.6
T2B (5G connectivity – transport paths)	17.6	23.1	17.6
T2 once T1 is achieved	50.8	76.4	50.8
T3 (Gigabit connectivity)	113.1	115.4	5.1
T4 FTTH in extreme rural geotype	9.2	9.2	9.2
T4 (Rural connectivity)	206.6	211.2	119.4
EGS (premises)	271.9	311.2	184.7
EGS (premises+companies)	370.5	411.6	185.3

Source: Own calculations

Table 11. Summary of EGS investment needs (b€) in the EU-27

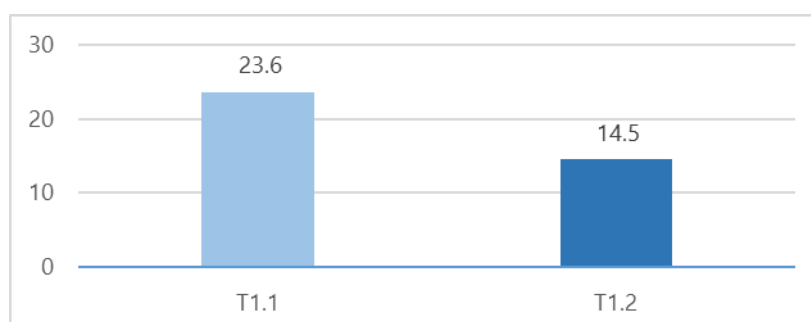
EU-27	Baseline	Max	Min
T1 (intermediate connectivity – major city)	12.7	20.7	12.7
T2A (5G connectivity – urban areas)	36.4	58.4	36.4
T2B (5G connectivity – transport paths)	16.4	21.5	16.4
T2 once T1 is achieved	43.3	64.6	43.3
T3 (Gigabit connectivity)	104.0	106.1	4.7
T4 FTTH in extreme rural geotype	9.2	9.2	9.2
T4 (Rural connectivity)	184.6	188.7	103.3
EGS (premises)	240.6	274.0	159.3
EGS (premises+companies)	331.7	366.8	160.8

Source: Own calculations

### Intermediate Connectivity – 5G available in a major city in each Member State by 2020 (T1)

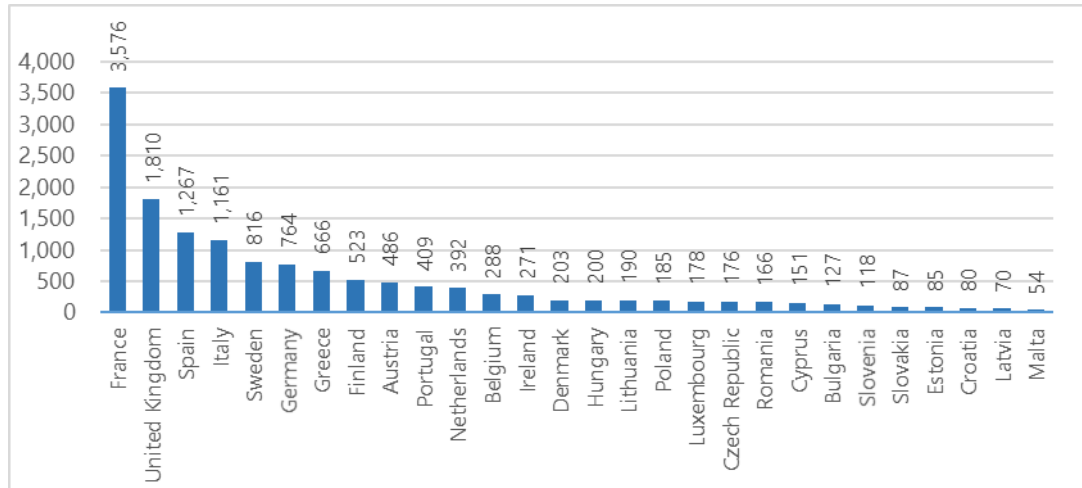
The investment needed to complete the Intermediate Connectivity objective (T1) amounts to 14.5 b€ in the baseline scenario (T1.2 “nominal quality”). Choosing a higher quality for 5G provision increases the investment to 23.6 b€.

Exhibit 9. Investment needed to complete availability of 5G in the capital city of each EU Member State by 2020 (T1) in b€



At country level, the investment simply depends on the size and population of the capital region of each Member State, with France (3.5 b€), UK (1.8 b€) and Spain (1.2 b€) leading the baseline for T1.

Exhibit 10. Investment needed to complete availability of 5G in the capital city of each EU Member State by 2020 (T1 baseline: T1.2 “nominal quality”) in m€



### 5G Connectivity – 5G uninterrupted coverage in all EU urban areas and major terrestrial transport paths by 2025 (T2)

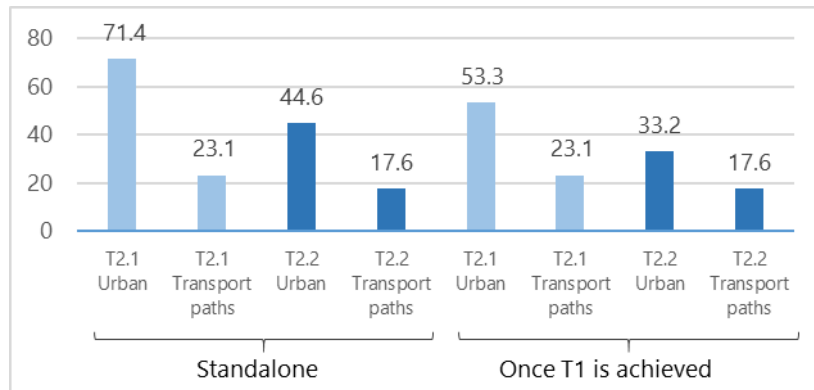
The investment needed to complete the 5G Connectivity objective (T2) amounts to 62.2 b€ in the baseline scenario (T2.2 “nominal quality”). Choosing a higher quality for 5G provision increases the investment to 94.5 b€.

This objective can be divided into two different parts: 5G coverage in urban areas and 5G coverage in major terrestrial paths. The baseline scenario for urban areas requires an investment of 44.6 b€, while terrestrial paths including railways need 17.6 b€. In the case of higher quality in the provision of 5G the urban expenses would increase to 71.4 b€ and for terrestrial paths it would be 23.1 b€.

Analysis Mason (2016) in its study on ubiquitous connectivity provides 5.2 b€ for railways, 6.7 b€ when motorways are also included, 28 b€ when state roads are added - the option favoured by the EC (European Commission, 2016)- and finally 103 b€ if also provincial roads are considered. Although Analysis Mason (2016) does not provide figures for coverage of urban areas with 5G and only global figures, this study has extended the 5G coverage for all the premises for a sense of comparison. Analysis Mason figure for guaranteed quality amounts to 222 b€ compared to this study similar figure of 228.3 b€. In the case of nominal quality there is higher difference: Analysis Mason 79 b€ vs. this study at 116.5 b€.

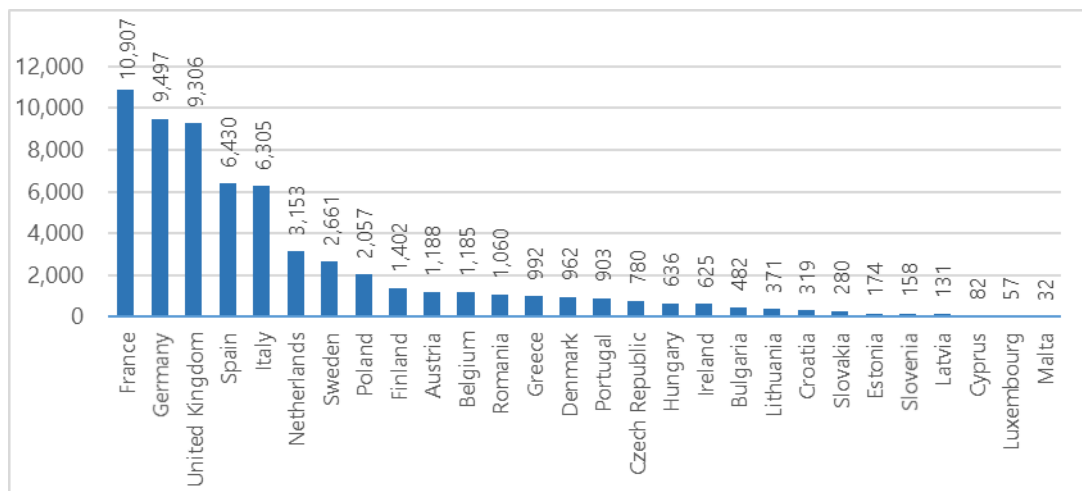
If 5G Connectivity (T2) takes place after the deployment of the Intermediate Connectivity objective (T1), then the total investment decreases to 50.8 b€ in the baseline scenario and to 76.4 b€ in the case of the higher quality scenario.

Exhibit 11. Investment needed to provide uninterrupted coverage of 5G in all EU urban areas and major terrestrial transport paths by 2025 (T2) in b€



At country level, the investment needed is highest in France (10.9 b€), Germany (9.5 b€), and UK (9.3 b€). Together they account for almost 50% of the total investment need. The less investment is required in those countries with smaller territory and population: Malta, Luxembourg, Cyprus, Latvia, Slovenia, Lithuania and Estonia.

Exhibit 12. Investment needed to provide uninterrupted coverage of 5G in all EU urban areas and major terrestrial paths in each Member State by 2025 (T2 baseline: T2.2 “nominal quality”) in m€



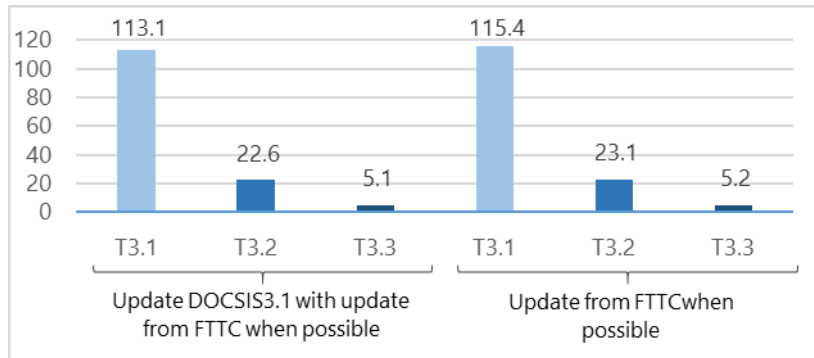
### Gigabit Connectivity for all EU socio-economic drivers by 2025 (T3)

The investment needed to complete the Gigabit Connectivity objective (T3) amounts to 113.1 b€ in the baseline scenario (T3.1 “all enterprises”)<sup>32</sup>.

Choosing only 5 millions of EU companies and institutions decreases the investment to just 22.6 b€ and limiting the number to 1 million enterprises and institutions causes the investment to be as little as 5.1 b€.

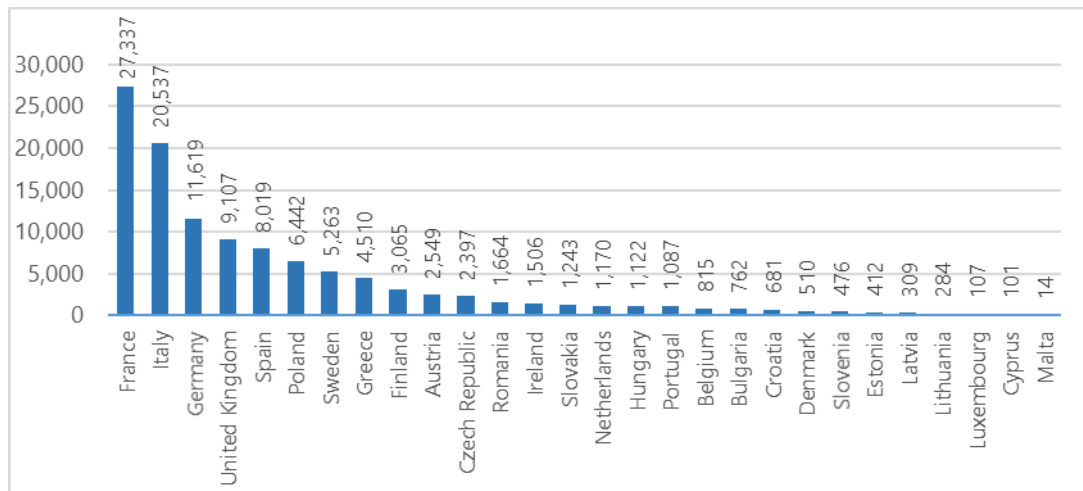
<sup>32</sup> A value lower than the value from Scenario D in Analysis Mason (2016) at 149 b€, since the latter uses 4 million more companies and 10 additional millions of teleworkers and freelancers. Using Analysis Mason scenario then the Gigabit Connectivity baseline would increase to 137.3 b€.

Exhibit 13. Investment needed to provide 1 Gbps connectivity<sup>33</sup> for all EU socio-economic drivers by 2025 (T3) in b€



At country level, the investment needed is highest in Italy (27.3 b€) due to its particular combination of companies’ population and lack of FTTH, followed by France (20.5 b€) and Germany (11.5 b€). Together they account for more than 50% of the total investment need. The less investment is required in those countries with smaller size: Malta, Cyprus, Luxembourg, Lithuania, Latvia, Estonia, Slovenia, Denmark, Croatia and Bulgaria.

Exhibit 14. Investment needed to provide 1 Gbps connectivity for all EU socio-economic drivers in each Member State by 2025 (T3 baseline: T3.1 “all enterprises”) in m€



### Rural Connectivity – 1 Gbps connectivity for all EU households by 2025 (T4)

The investment needed to complete the Rural Connectivity objective (T4) amounts to 206.6 b€ in the baseline scenario<sup>34</sup> (T4.1 “extreme-rural wireless”) where upgrade of DOCSIS has been considered, and to 211.2 b€ if the DOCSIS upgrade is not used.

If the wireless option is extended to include the three rural geotypes, the investment required decreases to 119.4 and 123.8 b€ with and without DOCSIS upgrade

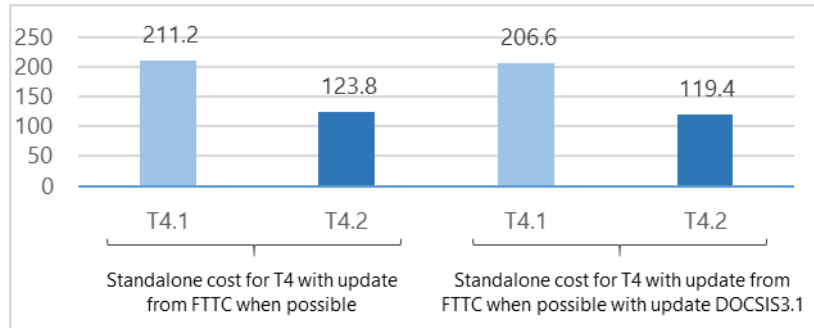
<sup>33</sup> DOCSIS update is only applicable to reach 1Gbps. For the rest of the calculations it is considered that it can reach 100Mbps.

<sup>34</sup> These results are relatively similar to Analysis Mason (2016) in its Scenario E for Rural Connectivity fully based on fibre that estimated the investment needed at 183 b€. The FTTH Council Europe (FTTHCE, 2017) estimates a fully-fibre deployment at between 137 and 156 b€ depending on the cost saving from sharing existing infrastructures, but it does not consider the extension to 1 Gbps that would add about 30 to 50 b€ to these figures.



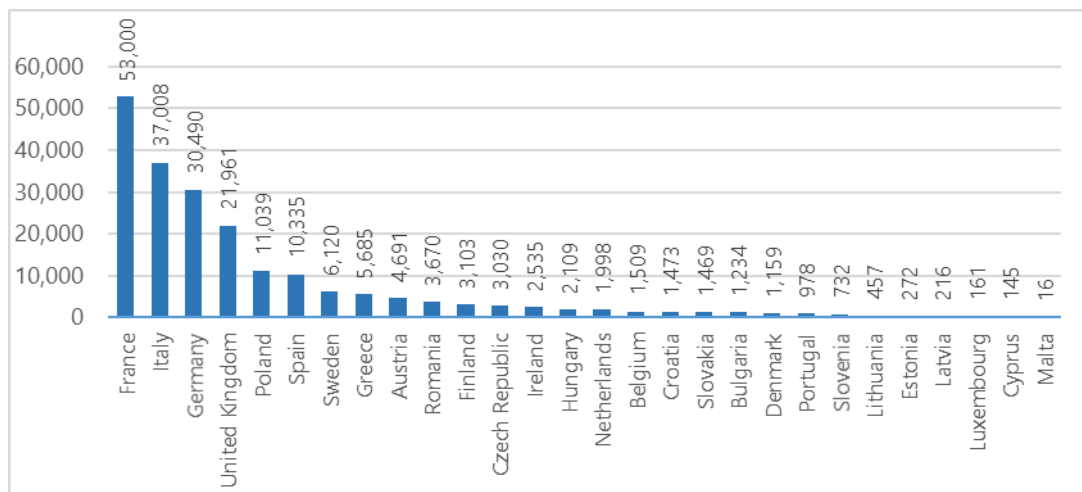
respectively, both figures lower than the EC (European Commission, 2016) combination of fibre and wireless for this objective at 127 b€.

Exhibit 15. Investment needed to provide 1 Gbps connectivity for all EU households by 2025 (T4) in b€



At country level, the investment needed is highest in France (53.0 b€), followed by Italy (37.0) and Germany (30.5 b€). Together they account for almost 60% of the total investment needed. The less investment is required in those countries with smaller size and/or already rather developed broadband networks: Malta, Cyprus, Luxembourg, Latvia, Estonia, Lithuania, Slovenia and Portugal.

Exhibit 16. Investment needed to provide 1 Gbps connectivity for all EU households by 2025 (T4 baseline: T4.1 "extreme-rural wireless") in m€



### European Gigabit Society investment need by 2025 (T1+T2+T3+T4)

Combining T1 and T2, with the assumption of the former achieved before the latter and adding T3 and T4 provides the investment needed to complete the EGS targets in 2025. Therefore, the baseline<sup>35</sup> for the EGS amounts to 370.5 b€.

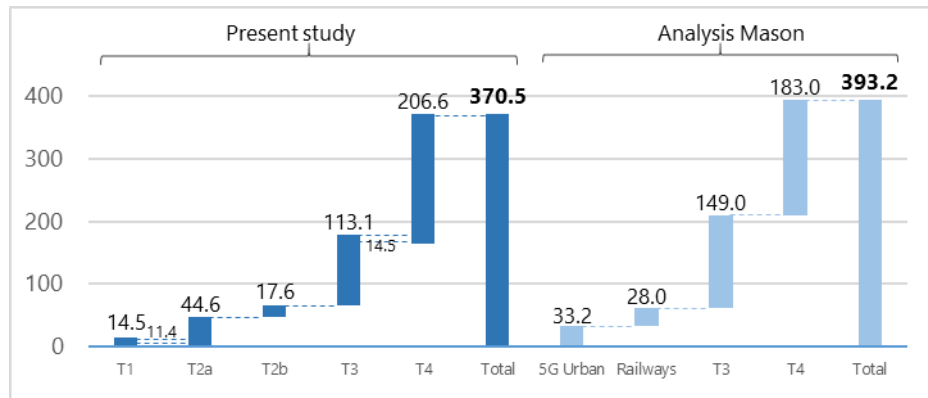
Using higher quality in wireless provision for 5G increases the investment to 412.1 b€. In a similar scenario, EC (European Commission, 2016) estimated the EGS objectives cost for the period 2018-2025 at 443 b€. On the contrary if wireless technologies are

<sup>35</sup> The baseline scenario is calculated as the sum of Scenarios T1.2 and T2.2 (both "nominal quality") + Scenarios T3.1 "all enterprises" + T4.1 "extreme-rural wireless".

chosen for the three rural geotypes in the case of Rural Connectivity, then the EGS investment need drops to 175.3 b€.

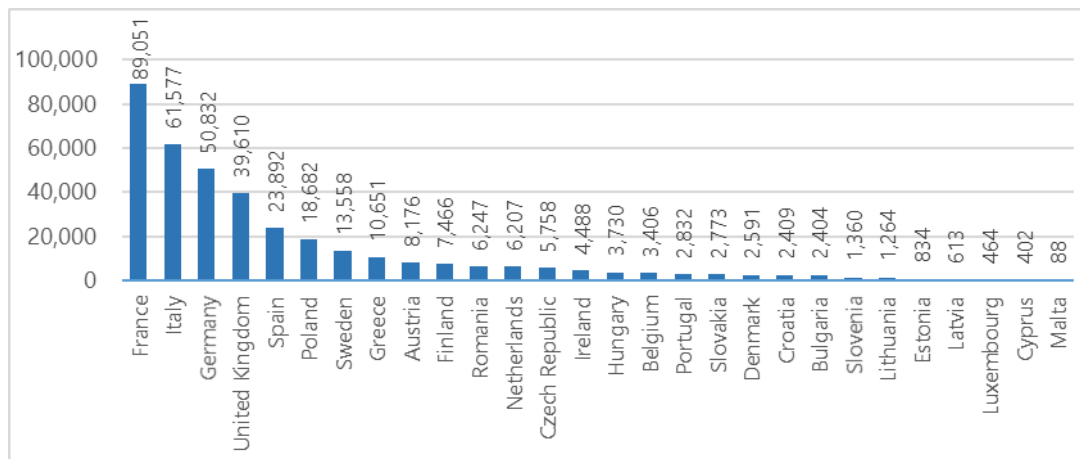
If only premises are considered, this is, not including the effect of Gigabit Connectivity (T6), then the EGS investment need for premises in the baseline case is 271.9 b€.

Exhibit 17. Investment need to achieve EGS targets (T1 + T2 + T3 + T4) by 2025 in b€



At country level, just France (89.1 b€), Italy (61.6) and Germany (50.8 b€) account for more than 54% of the baseline investment need. On the contrary, the investment needs to complete EGS according to the baseline scenario in Malta, Cyprus, Luxembourg, Latvia, Estonia and Lithuania is the less costly.

Exhibit 18. Investment need to complete the EGS targets (T1 + T2 + T3 + T4) by 2025 by Member State (T1+T2 baseline: T1.2 + T2.2 "nominal quality", T3 baseline: T3.1 "all enterprises", T4 baseline: T4.1 "extreme-rural wireless") in m€



In terms of premises, the model shows that there is still a 42% gap (105 m premises) without EGS targets coverage as of 2018.

The 2018 EGS investment gap can also be analyzed as a function of geotype, as shown in the table below. As expected, the gap is higher in rural areas, and it is also in these rural areas where the most advanced fixed technologies are missing, FTTH in particular. Also, while the share of the gap in rural areas is 32% of premises vs. 68% in urban and suburban areas, its weight in terms of investment is much higher, a 52% share vs. a 48% share in urban areas. The difference between urban and rural areas is also highlighted

through the change in the cost per premise from urban areas into rural areas, which is three times higher in rural and extreme-rural. The cost of extreme-rural areas is comparatively low since it uses 5G at nominal quality.

Table 12. 2018 EGS (premises) investment gap by geotype

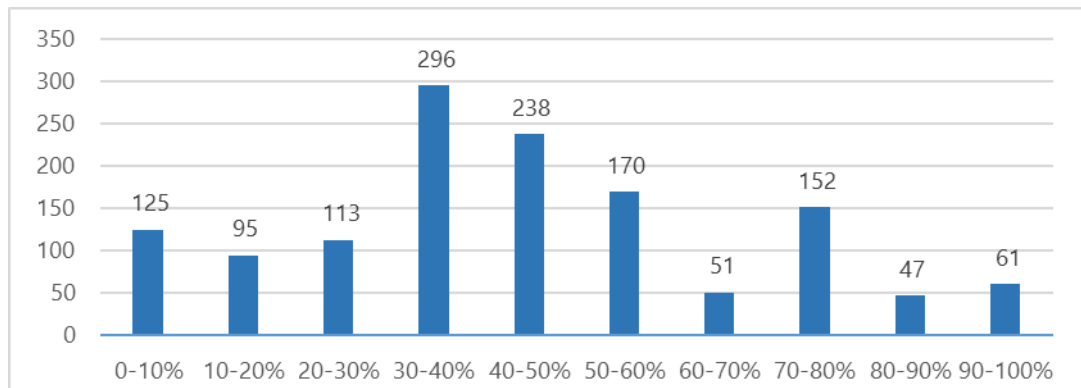
EGS (premises)	Urban	Suburban	Semi-rural	Rural	Extreme rural
Share of gap in number of premises	32%	36%	21%	10%	1%
Share of gap in terms of investment	21%	27%	30%	20%	2%
Total investment (b€)	57.7	72.0	81.7	54.3	6.2
Average investment per premise (€)	505	571	1,105	1,542	1,572

### NUTS3 analysis of EGS investment

This same investment need can be further analysed per NUTS3. Exhibit 32 below shows the histogram of the gap in percentage of premises.

From the total 1,348 NUTS3 areas in the EU-28, the population living in NUTS3 areas with no gap is expected to be 5% of the EU-28, 22% of population in NUTS3 areas with a gap less than 25%, 36% of the EU population living in NUTS3 areas with a gap between 25% and 50%, 23% of the EU population with a gap between 50% and 75%, and 14% of the population living in NUTS3 regions with a gap higher than 75%.

Exhibit 19. Histogram of number of NUTS3 regions as a function of the EGS investment need (% premises) in the EU-28



### EGS investment break up

It is also possible to break up the EGS investment in different components. UK accounts for about 11.5% of the total investment need across scenarios.

The urban – rural divide has been already investigated with urban and suburban pending investment lower than rural, 45% vs. 55%, in spite of the urban 76% share of premises. Including companies in the calculations increases the investment 36% above the premises baseline, while considering households decreases the funding in about

11%. Looking into cohesion regions, their share of the total investment for EGS is 36% of the total.

Table 13. Break-up of EGS investment needs EU28 (b€)

	Baseline	Max	Min
EGS (Total households)	240.7	280.0	153.5
EGS (Total premises)	271.9	311.2	184.7
EGS (Total premises + companies)	370.5	411.6	185.3
EGS (households vs. premises)	89%	90%	83%
EGS (premises + companies vs. premises)	136%	132%	100%
EGS (EU-27) (premises)	88%	88%	86%
EGS (UK)	12%	12%	14%
EGS (urban + suburban)	41%		
EGS (semi-rural, rural and extreme-rural)	59%		
EGS (cohesion regions)	36%	35%	33%
EGS (non-cohesion regions)	64%	65%	67%
EGS (expected operators investment) (premises + companies)	33%	38%	65%
EGS (expected investment gap)	67%	62%	35%

Source: own calculations

After incumbent and/or alternative operators roll out in the period 2018–2025, the model estimates that the remaining gap to achieve EGS targets in 2025 amounts to 249 b€. This is a higher figure to EC estimates of 155 b€ (European Commission, 2016), but similar to Analysis Mason (2016) at 251 b€. Therefore, deployment from existing operators is expected to reduce the high-speed broadband investment gap by one third of the initial total investment need in the baseline scenario. Note however, that in the minimum scenario, the situation is reversed and the operators' investment almost covers two thirds of the total investment.

#### 4. Conclusions

This study's main conclusion is that the EU in general requires a very high level of investment in high-speed broadband networks to achieve the EGS targets in 2025, with most of the gap taking place in suburban, semi-rural and rural geotypes. In fact, it seems that there is a considerable consensus among market analysts and experts on these issues, putting the figure on the investments needed for the EGS targets in the range of 370 to 395 b€ for the EU-28 at 5G nominal quality and 340 to 365 b€ for the EU-27, with about one third of this figure potentially coming from already expected private funding, and therefore leaving an investment gap of about 250 b€.

There is also a great deal of consensus about the need for additional policy interventions and more public funding in order to achieve the EGS targets. In simple terms, the private sector is reluctant to invest and close the gap, as investors in broadband infrastructure can only partially appropriate benefits due to the public good

features of broadband connectivity (Gruber et al., 2014), a result also displayed in most of the theoretical and empirical studies available on the relationship between broadband deployment and regulatory measures (Cambini & Jiang, 2009).

In the baseline scenario, the investment needed to meet EGS targets adds up to 370 b€. But this figure can also become considerably different in alternative scenarios. A preference for fibre-based technologies in the extreme-rural geotypes combined with higher quality for 5G deployments increases 11% the size of the investment. On the contrary, if wireless technologies at nominal quality are allowed in all the three rural geotypes and not just in the extreme-rural case, the investment decreases down to 50% compared with the baseline scenario.

In addition to the general analysis, there is also the possibility of looking into the NUTS3 areas and the countries themselves, since there are a number of them that are expected to almost or even achieve the EGS targets before 2025. When exploring the reasons for their success, different types of situations can be found, such as countries that have used past investments, mostly in cable (Belgium, Denmark, Malta, Portugal, the Netherlands), and countries that rely on existing investment plans for operators and support from the government as well as leveraged investments (Estonia, Latvia, Lithuania, Luxembourg). There could be some temptations to explain these successes. All of them are relatively small countries with good departing coverage. Some are also highly urbanised and homogeneous with relatively high income: Belgium, Denmark, Luxembourg, and the Netherlands. Their rural sector is small in absolute terms. There are also other small countries in which cable technologies have a strong footprint, including the three countries just mentioned, but also Estonia, Latvia, Lithuania, Malta, and Portugal. These last five also have comparatively low-cost levels for deployment. In taking the cable case further the differences are considerable. In Latvia, cable providers are seen as television providers with only limited high-speed broadband adoption. In Denmark, early attempts at an integrated fibre-cable network solution paved the way for the incumbent to provide cable television. In the Netherlands, a municipal initiative led to consolidation of cable provision in separated regional providers, creating a true infrastructure-based competition situation (see Lemstra and Melody [2015a] for a detailed account of differences in broadband dynamics across Europe). Neither general socio-economic conditions nor market behaviour explain all cases, therefore, the most reasonable conclusion is that each country has its own path<sup>36</sup>, and much still depends on economic pre-conditions, market interest, and political will regarding high-speed broadband deployment.

From the perspective of NUTS3 areas, the results presented in this paper display the existence of a considerable premises investment gap in the mid to long term in about one third of the NUTS3 regions in Europe (with about 37% of the EU population), the

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<sup>36</sup> According to Lemstra and Melody (2015b), the broadband market dynamics depend on geography and demography, historical infrastructure deployment, institutional arrangements, time of joining the EU, market structure, distribution of market power, firm ownership, position and role of the regulator, political priorities and preferences, and the industrial setting.

absence of fibre deployment in rural geotypes and the digital-divide-within-a-digital-divide in rural areas (Rendon Schneir & Xiong, 2016).

All in all, the EU requires action if the EGS targets are to be met. Telecommunications network deployments are slow by nature, as they require design, planning, coordination, and permission from local authorities, with typical projects requiring three or more years from the drawing table and financial agreements to deployment fruition. Thus, the identification of new public and private sources of investment and the case to attract them into the broadband business arena seems to be the final frontier for the fulfilment of EU high-speed broadband EGS targets.

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## Annex. 1 Gbps initiatives and commitments in the EU

Table 14. Gbps networks initiatives and commitments in the EU (2018)

Country	Operator	Households (m)	Target year	Source
Austria				
Belgium				
Bulgaria				
Croatia				
Cyprus	CYTA	0.2	2028	<a href="https://cyprus-mail.com/2018/07/05/cyta-launches-fibre-optic-network/">https://cyprus-mail.com/2018/07/05/cyta-launches-fibre-optic-network/</a>
Cz Republic				
Denmark	TDC	Half	2017	<a href="https://www.huawei.com/en/press-events/news/2016/1/Huawei-and-TDC-Group">https://www.huawei.com/en/press-events/news/2016/1/Huawei-and-TDC-Group</a>
Denmark	TDC	Whole	2018	<a href="https://www.digitalveurope.com/2016/01/27/tdc-pledges-denmark-wide-1gbps-broadband-in-2018/">https://www.digitalveurope.com/2016/01/27/tdc-pledges-denmark-wide-1gbps-broadband-in-2018/</a>
Estonia	Starman	0.05	2022	<a href="https://www.zdnet.com/article/like-the-sound-of-10-gigabit-internet-everywhere-then-move-to-estonia/">https://www.zdnet.com/article/like-the-sound-of-10-gigabit-internet-everywhere-then-move-to-estonia/</a>
Finland	DNA	0.6	2017	<a href="https://www.telegeography.com/products/commsupdate/articles/2016/05/10/dna-finland-launches-gigabit-broadband/">https://www.telegeography.com/products/commsupdate/articles/2016/05/10/dna-finland-launches-gigabit-broadband/</a>
France				
Germany	Deutsche telekom	0.04	2019	<a href="https://www.telekom.com/en/blog/group/article/broadband-facts-versus-legends-516794">https://www.telekom.com/en/blog/group/article/broadband-facts-versus-legends-516794</a>
Greece	OTE	1	2022	<a href="https://www.telecompaper.com/news/ote-to-provide-1-mln-households-businesses-with-access-to-ftth-network--1238409">https://www.telecompaper.com/news/ote-to-provide-1-mln-households-businesses-with-access-to-ftth-network--1238409</a>
Hungary	Digi	0.7	-	<a href="https://bbj.hu/business/digi-to-expand-1-gbps-internet-to-all-customers_148197">https://bbj.hu/business/digi-to-expand-1-gbps-internet-to-all-customers_148197</a>
Ireland	Siro (Vodafone&ESB)	0.5	2018	<a href="https://www.siliconrepublic.com/comms/siro-south-east-ireland-fibre-broadband-axione-obelisk">https://www.siliconrepublic.com/comms/siro-south-east-ireland-fibre-broadband-axione-obelisk</a>
Italy	TIM	2.7	2018	<a href="http://www.telecomitalia.com/tit/en/about-us/business/rete-strategia.html">http://www.telecomitalia.com/tit/en/about-us/business/rete-strategia.html</a>
Latvia	Latttelecom	0.492	2014	<a href="https://www.computerweekly.com/news/2240214496/Latvias-Latttelecom-1Gbps-will-be-standard-by-2018">https://www.computerweekly.com/news/2240214496/Latvias-Latttelecom-1Gbps-will-be-standard-by-2018</a>
Lithuania	Skynet	0.119	2016	<a href="https://www.telecompaper.com/news/skynet-claims-fastest-broadband-in-lithuania--1126430">https://www.telecompaper.com/news/skynet-claims-fastest-broadband-in-lithuania--1126430</a>
Luxembourg	LuxConnect	Whole	2020	<a href="https://www.luxconnect.lu/dark-fiber/">https://www.luxconnect.lu/dark-fiber/</a>
Malta	Melita			
Netherlands				
Poland	Orange Poland	1.7	2018	<a href="https://www.telecompaper.com/news/orange-poland-upgrades-top-broadband-speed-to-1-gbps--1257856">https://www.telecompaper.com/news/orange-poland-upgrades-top-broadband-speed-to-1-gbps--1257856</a>
Portugal		2.75	2016	<a href="https://www.vodafone.com/content/index/about/policy/news/public-policy-news-releases/2015/gigabit-fibre-europe.html">https://www.vodafone.com/content/index/about/policy/news/public-policy-news-releases/2015/gigabit-fibre-europe.html</a>
Romania				
Slovakia	Slovak Telekom	0.5	2018	<a href="https://www.telecompaper.com/news/slovak-telekom-offers-1-gbps-speed-over-fibre-as-add-on--1238941">https://www.telecompaper.com/news/slovak-telekom-offers-1-gbps-speed-over-fibre-as-add-on--1238941</a>
Slovenia				<a href="https://www.telegeography.com/products/commsupdate/articles/2013/04/26/vahta-challenges-ftth-rural-reluctance/">https://www.telegeography.com/products/commsupdate/articles/2013/04/26/vahta-challenges-ftth-rural-reluctance/</a>
Spain	Orange	12	2018	<a href="http://blog.orange.es/adsl-fibra/lanzamos-fibra-1gbps-simetrico-12-millones-hogares-wi-fi-inteligente/">http://blog.orange.es/adsl-fibra/lanzamos-fibra-1gbps-simetrico-12-millones-hogares-wi-fi-inteligente/</a>
Spain	Vodafone	10.3	2018	<a href="https://www.elespanol.com/economia/empresas/20180725/vodafone-podra-gbps-clientes-red-vuelta-cole/325217964_0.html">https://www.elespanol.com/economia/empresas/20180725/vodafone-podra-gbps-clientes-red-vuelta-cole/325217964_0.html</a>
Sweden	Stokab	0.4	2018	<a href="http://www.ftthcouncil.eu/documents/FTTH_Council_report_FINAL_and_proofread-update-20180214.pdf">http://www.ftthcouncil.eu/documents/FTTH_Council_report_FINAL_and_proofread-update-20180214.pdf</a>
UK	Government project			<a href="https://www.gov.uk/government/news/six-areas-to-pilot-uks-fastest-broadband-as-part-of-200-million-project">https://www.gov.uk/government/news/six-areas-to-pilot-uks-fastest-broadband-as-part-of-200-million-project</a>
UK	Openreach / BT	3	2020	<a href="https://www.homeandbusiness.openreach.co.uk/fibre-broadband/ultrafast-broadband/ultrafast-fibre-fttp?utm_source=ultrafastfttpfurl&amp;utm_medium=Campaignfurl&amp;utm_campaign=ultrafastfttp+furl">https://www.homeandbusiness.openreach.co.uk/fibre-broadband/ultrafast-broadband/ultrafast-fibre-fttp?utm_source=ultrafastfttpfurl&amp;utm_medium=Campaignfurl&amp;utm_campaign=ultrafastfttp+furl</a>

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