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5G Observatory

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Up to January 2022

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1 Introduction

This is the fourteenth quarterly report of the European 5G Observatory (fourth quarter of 2021).

Since January 2022, commercial 5G is now available in all 27 EU Member States.[1]

Compared to previously communicated results, some progress has been recorded in terms of the level of spectrum assignments in the pioneer bands. However, all the objectives set for the three pioneer bands in the 2016 5G Action Plan for Europe have not yet been achieved in all Member States. The number of Member States which have assigned spectrum in all three pioneer bands remained unchanged compared the end of October 2021, when only seven EU Member States having reached that important milestone.

5G spectrum auctions have resumed after the pandemic slowdown but there are still to date five Member States that have failed to assign any spectrum from the 5G pioneer bands.

This chapter presents a brief (partly visual) summary of EU-27 and an overview of comparable international trends.

[1] The first commercial 5G service has been launched in Lithuania in January 2022 at the time of this report publication, completing EU27 deployment in 2022
Source: Telia

1.1 Summary of recent developments

The three sub-sections below outline key developments in both the EU and internationally since the publication of the last 5G Observatory Quarterly report in October 2021, focusing on spectrum awards, policy and commercial launches.

1.1.1 5G spectrum awards

In the EU, the vast majority of Member States have assigned at least one band for 5G. In addition, the following countries have carried out awards in 5G target bands during the last three months:

- December 2021: Latvia completed its 700 MHz auction, raising a total of €13 million.[2]
- November 2021: Romania conducted its 800 MHz, 2.6 GHz and 3.5 GHz auction[3]

Internationally, there were also a series of 5G spectrum auctions. The following list details notable 5G auctions that have taken place outside of the EU in the last three months:

- October 2021: Norway completes its 2.6 GHz and 3.6 GHz auction, raising a total of €390 million Euros.[4]
- November 2021: Brazil concluded its auction of the 700 MHz, 2.3 GHz, 3.5 GHz, and 26 GHz bands, raising €1.1 billion.[5]
- November 2021: The United States has finished the auction phase of its 3.45 – 3.55 GHz auction. The full results have yet to be published.[6]
- December 2021: Nigeria completed its 3.5 GHz auction, raising a total of €1.2 million.[7]

1.1.2 Policy

In the EU, there appears to be continued interest in local 5G licensing models. Sweden announced in December that it was accepting applications for local licenses in the 3.6 GHz and 26 GHz bands.

In Poland, a controversial law to establish a state owned 5G network is being explored. This network would be operated by a state run operator in the 700 MHz band.[8]

On an international level, a disagreement between two federal agencies in the United States has been developing. The Federal Aviation Authority (FAA) has expressed worries about the potential

[2] https://www.sprk.gov.lv/events/sprk-apstiprinati-5g-700-mhz-diapazona-radiofrekvencu-izsoles-rezultati-valsts-budzeta
[3] https://www.ancom.ro/licita539ia-din-acest-an-pentru-alocarea-de-spectru-s-a-finalizat_6392
[4] https://www.nkom.no/aktuelt/the-norwegian-5g-auction-has-concluded
[5] https://www.policytracker.com/brazil-rakes-in-1-3-billion-in-puzzling-5g-auction/
[6] https://www.fcc.gov/document/fcc-mid-band-spectrum-auction-successfully-concludes-clock-phase
[7] https://www.ncc.gov.ng/media-centre/news-headlines/1137-5g-mafab-mtn-emerge-winners-in-nigeria-s-3-5ghz-spectrum-auction
[8] https://www.policytracker.com/polish-government-amends-law-to-launch-state-owned-5g-network-operator/)

for interference between the part of the C-band used in the US for 5G deployment and radio altimeters in aeroplanes. Although the country’s spectrum regulator the FCC has disputed this claim, mobile operators have agreed to push back their planned 5G rollouts[9]. Deployment has resumed in January 2022.

1.1.3 Commercial launches

As of January 2022, commercial 5G services are now available for the first time in all 27 EU Member States. This is the consequence of the recent commercial 5G launches that have taken place in both Lithuania and Portugal.

In Portugal, operator NOS announced in December 2021 that it was the first operator in the country to launch 5G services.[10] In Lithuania, Telia announced in January that it has launched 5G services in the country using the 2.1 GHz band.[11]

In other EU countries, the number of operators providing 5G services continues to grow. In Malta, national operator Epic announced that it had launched 5G services.[12] Belgian operator Telenet has also begun providing 5G services using provision spectrum.[13]

[9] https://5gobservatory.eu/us-operators-delay-c-band-5g-rollout-after-aviation-sector-warning/
[10] https://5gobservatory.eu/portuguese-operator-nos-launches-5g/
[11] https://www.telia.lt/pranesimai-spaudai/-telia-vilniuje-jungia-5g-rysi-komerciniais-dazniais
[12] https://5gobservatory.eu/epic-launches-5g-in-malta/
[13] https://5gobservatory.eu/telenet-to-launch-5g-in-belgium-using-provisional-spectrum/

1.2 5G scoreboard

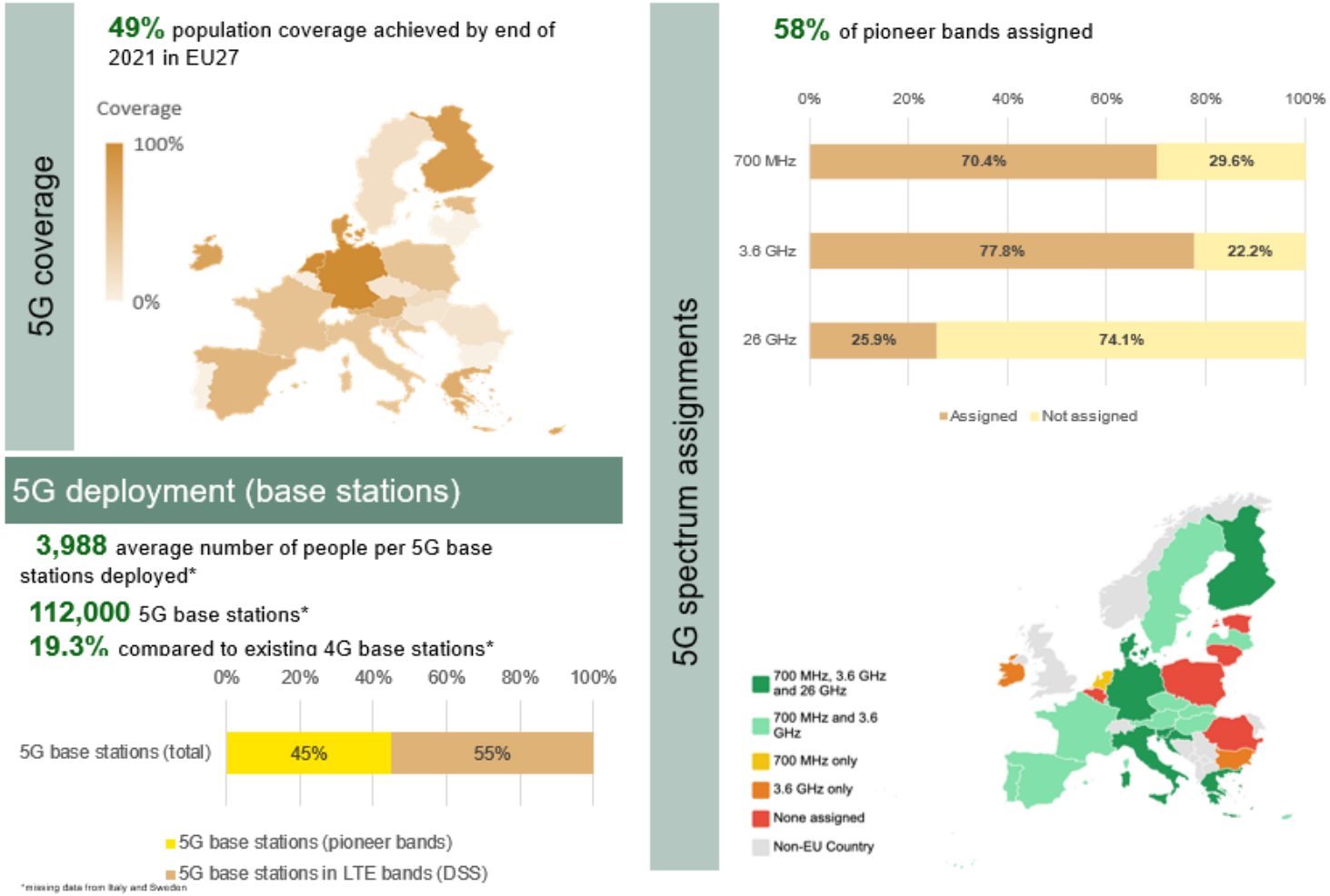
1.2.1 EU27

The 5G scoreboard summarises the status of 5G commercial launches, spectrum assignments and 5G corridors in EU-27. To date:

- All EU countries have commercial 5G service available at least in a part of the country.
- 17 Member States are now involved in the preparation of twelve 5G cross border corridors with the aim to stimulate the use of 5G in transport services, in particular to pave the way for Connected and Automated Mobility.
- There was a 5% increase in the weighted total amount of pioneer bands assigned since the last 5G Observatory report.
- A total of 112,000 5G base stations[14] are now active in the EU (excluding Italy and Sweden from which numbers were not available at the time of publication).
- 50% of households across the EU27 were reached by at least one 5G network at the end of 2021[15].

[14] These data are preliminary statistics based on publicly available information. Until a formal data collection is established, these figures should be then considered as indicative only.
[15] Broadband Connectivity in Europe 2020

Figure 1: Overview of 5G developments



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1.2.2 International

The international version of the scoreboard details status for 5G commercial launches and spectrum plans worldwide, including metrics such as “people per base station” which represents the country’s population divided by the number of base stations deployed. The following developments can be highlighted[16]:

- China has nearly 1 million installed 5G base stations: eight times more than the EU and 18 times more than the USA.
- South Korea has the most 5G base stations per head of population: 13 times more than the EU and 20 times more than the USA.
- The USA has assigned the most mmWave spectrum: four bands in total, compared to one in some of the EU and none in China.
- All the major economies studied have assigned 5G low band spectrum in 600 MHz or 700 MHz, except South Korea and Japan.

[16] Please notice that there may be discrepancies between the reported figures, as the method for calculating the number of base stations is not standardised between regions

Figure 2: International 5G developments

	China	South Korea	Japan	USA	EU
5G Mode[6]	NSA/SA	NSA/SA	NSA/SA	NSA	NSA/SA
Approximate number of 5G base stations	916,000	162,000	50,000	50,000	112,000
Population	1,402,000,000	51,780,000	125,800,000	329,500,000	447,706,000
People per base station	1531	319	2516	6590	3988
5G target bands assigned	700 MHz 2.6 GHz 3.6 GHz	3.6 GHz 28 GHz	3.6 GHz 3.6 - 4.1 GHz 4.5 GHz 28 GHz	600 MHz 2.5 GHz 3.45 - 3.55GHz 3.5 - 3.7 GHz 3.7 - 3.98 GHz 24 GHz 28 GHz 39 GHz 47 GHz	700 MHz 3.6 GHz 26 GHz
Indicative 5G subscriber numbers	**166 million** (China Mobile only; source: China Mobile Research Institute) **173 million** (source: Ericsson 2020)	**17 million** (source: 5G Forum, Korea)	**14.19 million** (source: Japan times)	**15.8 million** (in Dec 2020; source: Insider Intelligence) **14 million** (including Canada; source: Ericsson 2020)	**8 million** (source: Ericsson 2020)

Country	Low-band (<1 GHz)	Mid-band (1 - 6 GHz)	High-band (>6 GHz)
China	700 MHz	2.6 GHz 3.6 GHz 4.9 GHz	-
South Korea	-	3.6 GHz	28 GHz
Japan	-	1.7 GHz 3.6 GHz 3.7 GHz 4 GHz 4.5 GHz	28 GHz
USA	600 MHz 850 MHz	2.5 GHz 3.45 - 3.55 GHz 3.5 - 3.7 GHz 3.7 - 3.98 GHz	24 GHz 28 GHz 39 GHz 47 GHz
EU	700 MHz	3.6 GHz	26 GHz

2 Key qualitative developments

The main focus of the 5G Observatory is to monitor developments in Europe taking into account international developments with possible direct or indirect impact on the European market. The aim is to understand developments in the space of 5G that might have a strategic impact on progress in Europe with regard to the 5GAP, Digital Decade and relevant policy targets which in turn affect the link between 5G and growth, employment or the competitiveness of European industry. These developments are grouped into the following 3 areas:

- **Market industry**: focusing on updates regarding commercial 5G service launches and coverage of networks deployed, international developments, 5G private networks, verticals vendors and other topics affecting 5G policy goals (e.g. EMF regulations).
- **Policy/regulatory:** setting the policy context related to 5G developments (Digital Decade) including updates on cross-border (5G corridor) initiatives, preparation and execution by public authorities of spectrum assignments for 5G, 5G cybersecurity toolbox implementation and sustainability aspects.
- **Research/ innovation:** highlighting public funding in support of 5G deployment and R&I both at EU and national level, expected to have a significant market impact.

2.1 Market / industry

2.1.1 Update on status of commercial launches and frequency usage

Since January 2022, commercial 5G is now available in all 27 EU Member States.[17]The table below provides an overview of commercial launches per operators offering 5G services across EU-27, detailing their frequency usage and where applicable, highlighting use of Dynamic Spectrum Sharing (DSS) technology, network configuration i.e. Non Standalone (NSA) vs. Standalone (SA) implementations and announced coverage targets.

Compared to the previous, thirteenth quarterly report, below are the changes/updates reported in Table 1:

- Belgium: The Belgian operator Telenet announced the deployment of its 5G mobile network using provisional spectrum in the 3.6 GHz band.
- Germany: Featuring both NSA and SA networks, Deutsche Telekom announced 90% of population coverage with 63,000 antennas at the end of 2021. In addition, over 3,500 5G antennas in the 3.6 GHz band have been technically updated for 5G standalone.

[17] The first commercial 5G service has been launched in Lithuania in January 2022 at the time of this report publication, completing EU27 deployment in 2022
Source: Telia

- Latvia: The operator Tele2 announced it will accelerate 5G rollout to achieve 99% of the country’s population by 2024.
- Lithuania: The first commercial 5G service has been launched by Telia in the 2100 MHz frequency band.
- Malta: The operator Epic has become the second telecom company to launch 5G services, selecting Ericsson as its exclusive 5G radio access network (RAN) provider.
- Portugal: Following the country’s spectrum auction in October 2021, the operator NOS has become the first one to launch 5G. to operate its 5G service, securing 100 MHz in the 3.6 GHz band and 2x10 MHz in the 700 MHz band.
- Slovakia: The operator O2 launched 5G services in 15 cities with its network relying on Ericsson’s 5G technology.

Table 1: Overview of commercial launches

Country	Summary
Austria	**Network operators offering 5G services: T-Mobile, Three and A1 Telekom** *T-Mobile - not specified, assumed to be NSA* In March 2019, the operator announced commercial launch using the 3.7 GHz band deploying 25 base stations in rural areas. The operator declared its implementation of Dynamic Spectrum Sharing technology. In May 2021, the operator announced the rollout of the 700 MHz band for 5G services in rural areas. By using also the 2100 MHz and 3.7 GHz bands, its 5G service covered more than a third of the Austrian population. *Three (Drei) – planned SA* With a plan to launch commercially in spring 2022, the operator started carrying out 5G standalone (SA) trials in Vienna. For this purpose, Drei intends to use its spectrum holdings in the 700 and 1500 MHz bands.[18] The aim is to be able to connect up to 1 million people and devices to the Internet on one square kilometre, in spring 2022[19].

[18] https://www.rcrwireless.com/20210707/5g/drei-starts-5g-standalone-trials-headquarters-vienna
https://www.speedtest.net/insights/blog/5g-austria-q1-q2-2021/
[19] The fastest 5G network in the country comes from Drei (in-24.com)

Country	Summary
	A1 Telekom – not specified, assumed to be NSA In January 2020, A1 Telecom launched its 5G network using the 3.5 GHz band. In April 2021, the operator announced that its 5G network covered 3.8 million people in both urban and rural parts of the country.
Belgium	**Network operators offering 5G services: Proximus, Telenet** *Proximus – not specified, assumed to be NSA* In April 2020, Proximus launched Belgium's first commercial 5G services using spectrum in its existing spectrum holdings (2.1 GHz) and within current EMF norms specified per region.[20] *Telenet – not specified, assumed to be NSA* Belgian telecom operator Telenet has announced plans to deploy its 5G mobile network in the country starting on December 6[21] using provisional spectrum in the 3.6 GHz band.[22]
Bulgaria	**Network operators offering 5G services: Vivacom, A1, Telenor** *Vivacom – not specified, assumed to be NSA* In September 2020, Vivacom launched the first commercial 5G network in Bulgaria in via Dynamic Spectrum Sharing (DSS) technology on the existing 1800 MHz and 2100 MHz bands. *A1 - not specified, assumed to be NSA* In November 2020, the operator A1 launched its 5G network using 3.6 GHz in Sofia. *Telenor - not specified, assumed to be NSA* Telenor launched in early June 2021 in the bigger cities in Bulgaria on the 3.6 GHz band.[23]
Croatia	**Network operators offering 5G services: Hrvatski Telekom** *Hrvatski Telekom - not specified, assumed to be NSA* Hrvatski Telekom's 5G network is based on the use of Dynamic Spectrum Sharing (DSS) technology to make use of the 2100 MHz band, and the newly

[20] Based on the Proximus 5G coverage map deployments meet EMF norms in Walloon and Flanders regions
[21] https://press.telenet.be/telenet-to-launch-5g-in-first-regions-around-leuven-antwerp-and-the-coast
[22] https://5gobservatory.eu/telenet-to-launch-5g-in-belgium-using-provisional-spectrum/
[23] https://www.telenor.bg/en/news/telenor-bulgaria-received-permit-use-5g-frequencies

Country	Summary
	acquired 700 MHz and 3600 MHz bands.[24] Its 5G network currently covers 45 Croatian cities and a population of 1.7 million.[25]
Cyprus	**Network operators offering 5G services: Cytamobile-Vodafone** *Cytamobile-Vodafone - not specified, assumed to be NSA* Cyta, the first operator in Cyprus to launch commercial 5G services, claimed to cover 70% of Cyprus’s population in February 2021 using its assignments in the 700 MHz and 3.6 GHz bands.[26] The operator is aiming to reach 98% of the population in 2022.
Czechia	**Network operators offering 5G services: Vodafone, O2 (Telefonica), T-mobile** Czechia already has three of its four major telecom companies in the process of rolling out 5G networks using the 3.7 GHz band. O2 is expected to use its newly acquired 700 MHz frequencies for national roaming as well as public protection and disaster relief services for public emergency and security bodies according to CTU. Operators that secured spectrum in the 3400-3600 MHz bands, namely Vodafone (NSA, with 20% of population coverage in February 2021), T-mobile (NSA)[27], as well as O2, would have to lease the frequencies to support "Industry 4.0" services.[28]
Denmark	**Network operators offering services: TDC, Telenor, Telia Denmark, Hi3G Access** *TDC - not specified, assumed to be NSA* In September 2020, TDC launched commercial 5G services in the 3.5 GHz band in Copenhagen, Odense, Tand Helsingør. Their aim was to achieve nationwide (80%) population coverage by the end of September 2020.[29] *Telenor Denmark - not specified, assumed to be NSA* In November 2020, Telenor Denmark activated its 5G network using the 3.5 GHz band. *Telia Denmark - not specified, assumed to be NSA*

[24] https://5gobservatory.eu/5g-spectrum/national-5g-spectrum-assignment/#1533308480063-1f8df429-431f
[25] https://www.t.ht.hr/en/Press/press-releases/5625/Hrvatski-Telekom-s-the-first-in-Croatia-to-launch-5G-roaming.html
[26] https://cyprus-mail.com/2021/02/02/5g-understanding-the-full-value-chain-cyta-ceo/
[27] 5G - T-Mobile.cz
[28] https://www.ctu.eu/press-release-ctu-has-auctioned-frequencies-700-mhz-and-3400-3600-mhz-bands
[29] https://investindk.com/insights/danish-5g-launch-on-7-september-has-huge-commercial-potential

Country	Summary
	In November 2020, Telia launched commercial 5G services using the 3.5 GHz band. According to the plan, Telia planned to provide 5G coverage to 75% of the population by the end of 2022[30]. *Hi3G Access - not specified, assumed to be NSA* In December 2020, Hi3g Access announced the official switch-on of its new 5G network using frequencies in the 700 MHz and 1800 MHz bands. In addition, the operator acquired spectrum in the 2100 MHz band (1920-1940/2110-2130 MHz), in the 3.5 GHz band (3.54-3.66 GHz) and in the 26 GHz band (26.5-27.5 GHz).[31] The operator also announced it expects to complete its nationwide network by mid-2022.
Estonia	**Network operators offering 5G services: Telia** *Telia - not specified, assumed to be NSA[32]* In November 2020, Telia launched a commercial 5G network using Ericsson's Dynamic Spectrum Sharing technology, enabling Telia to use its existing frequencies since the government has not yet auctioned off the 3.6 GHz licences for 5G.
Finland	**Network operators offering 5G services: Elisa Oyj, Telia, DNA** *Elisa Oyj – trialled SA[33]* The telecom operator Elisa Oyj claims to be the first in the world to launch a commercial 5G network and to have the most comprehensive network in Finland today[34]. The first 5G licences were made available in the 3.6 GHz band frequencies in autumn 2018. In October 2021, the operator declared that more than 60% of population is already living in its 5G network area[35]. *Telia – SA core [36]* At the end of 2019, Telia Finland launched 5G services using its 3.5 GHz spectrum. In March 2021, its 5G network reached circa 40% of the population. *DNA - not specified, assumed to be NSA*

[30] 5G | Everything you need to know about 5G in Denmark | How to get 5G | Telia
[31] https://5gobservatory.eu/5g-spectrum/national-5g-spectrum-assignment/#1533308861084-6bfc1e56-ea0b
[32] Collaboration announced with Nokia for SA implementation.
Source: https://www.lightreading.com/5g/telia-picks-nokia-for-standalone-5g-core-in-six-markets/d/d-id/764771
[33] Ericsson, Nokia ink new 5G deals with Finnish telco Elisa (rcrwireless.com)
[34] https://elisa.fi/5g/
[35] 5G network in Finland - Elisa
[36] Source: Ericsson.
Source:https://www.lightreading.com/5g/telia-picks-nokia-for-standalone-5g-core-in-six-markets/d/d-id/764771

Country	Summary
	In January 2020, the operator started selling mobile 5G subscriptions using its 3.5 GHz band. In June 2021, the operator said its 5G network covered 42% of the population.
France	**Network operators offering 5G services: Bouygues Telecom, Orange, SFR, Free** *Bouygues Telecom – planned SA* The operator confirmed the goal of achieving nationwide coverage by the end of 2021, while the current roll-out phase relies on the 3.5 GHz and 2.1 GHz bands. In 2023, Bouygues plans to switch on its 5G core network, paving the way for standalone 5G[37]. *Orange - planned SA* By March 2021, about 200 municipalities were covered with the operator’s 3.5 GHz 5G network. Orange France has planned to launch Standalone 5G network for enterprise customers in 2022 and for the retail customers in 2023[38]. *SFR – not specified, assumed to be NSA* In November 2020, SFR announced the launch of its 5G service using the 2.6 GHz and 3.5 GHz in the city of Nice. *Free - not specified, assumed to be NSA* In December 2020, Free launched its commercial 5G services thanks to its cell sites equipped with 700 MHz and 3.6 GHz frequencies. The operator announced its 5G network covers 70% of the population[39].
Germany	**Network operators offering 5G services: Deutsche Telekom, Vodafone, Telefonica** *Deutsche Telekom - NSA, with a number of SA capable antennae* The operator announced 90% population coverage, 63,000 antennas at the end of 2021. Deutsche Telekom uses spectrum in the 2.1 GHz band to provide customers with 5G coverage in less densely populated areas, while the 3.6 GHz band is used in large cities: over 3,500 5G antennas in the 3.6 GHz band have been technically upgraded for 5G standalone.[40] Dynamic Spectrum Sharing is also being deployed.

[37] Bouygues switches on 5G, squeezing ahead of Orange - Telecoms.com
[38] Orange France to launch standalone 5G networks next year | LTEto5G
[39] Free mobile - 5G network
[40] https://www.telekom.com/en/media/media-information/archive/turbo-for-fiber-and-5g-643014

Country	Summary
	Vodafone Germany - SA Vodafone is using the 1800 MHz band to provide 5G in densely populated cities, while the 700 MHz range is being deployed in rural areas. The 3.5 GHz band is being rolled out in high traffic areas. *Telefonica – planned SA*[41] Telefonica’s 5G network should cover more than 30% of the population by the end of 2021 in the 3.6 GHz band. The operator also plans to use the 700 MHz and 1800 MHz bands to expand its coverage. In rural areas, the company will use Dynamic Spectrum Sharing. The operator expects to reach around 50% of the population by the end of 2022 and the whole country by 2025.
Greece	**Network operators offering 5G services: Wind Hellas, Cosmote, Vodafone Greece** *Wind Hellas - not specified, assumed to be NSA* In December 2020, the operator announced it switched on its 5G mobile network a few days after winning frequencies in the country’s multi-band 5G spectrum auction. 5G-capable frequencies have been assigned in the 700 MHz, 3.7 GHz and 26 GHz bands were sold, alongside permits for the 2100 MHz range. The operator said its 5G population coverage is expected to exceed 60% by 2023. *Cosmote – not specified, assumed to be NSA* Cosmote launched its commercial 5G services in December 2020 in Athens Thessaloniki and other Greek cities. The company is aiming to cover over 50% of the population by the end of 2021. *Vodafone Greece – not specified, assumed to be NSA* In January 2021, Vodafone Greece became the third mobile operator to switch on its 5G network. The operator plans to cover 40% of the population by March 2022.
Hungary	**Network operators offering 5G services: Magyar Telekom, Telenor, and Vodafone** *Magyar Telekom – not specified, assumed to be NSA*

[41]https://www.telefonica.de/news/press-releases-telefonica-germany/2021/03/5g-for-30-percent-of-the-population-in-2021-5g-standalone-in-preparation-telefonica-deutschland-o2-launches-5g-expansion-turbo.html

Country	Summary
	In April 2020, the operator launched commercial 5G mobile network services in partnership with Ericsson. Telekom uses the 3.6 GHz , 2100 and 700 MHz frequency bands[42] *Telenor - not specified, assumed to be NSA* The most recent operator to launch commercial 5G, Telenor used its 700 MHz and 3600 MHz bands acquired in 2020.[43] *Vodafone Hungary - not specified, assumed to be NSA* In October 2019, Vodafone Hungary launched a commercial 5G service limited to Budapest, using its existing 3.5 GHz spectrum and ahead of Hungary’s March 2020 license auction where it won additional 3.5 GHz frequencies plus a 700 MHz license.
Ireland	**Network operators offering 5G services: Vodafone, Eir, Three Ireland** *Vodafone Ireland - not specified, assumed to be NSA* In August 2019, Vodafone Ireland launched 5G services in selected areas of five Irish cities using the 3.5 GHz band. *Eir - not specified, assumed to be NSA* In December 2019, Eir launched its 5G service using the 3.5 GHz band. The operator declares its 5G network covers over 70% of the population[44]. *Three Ireland - not specified, assumed to be NSA* In September 2020, Three Ireland launched commercial 5G services with Ericsson’s equipment using the 3.7 GHz band.
Italy	**Network operators offering 5G services: Vodafone, Telecom Italia (TIM), Windtre, Fastweb, Iliad Italia** *Not specified, assumed to be NSA* Italy has four operators with active 5G services. TIM recently announced a 5G cloud network and WindTre extended 5G dynamic spectrum sharing (DSS) to

[42] https://www.telekom.hu/lakossagi/english/customer-centre/coverage
[43] https://bbj.hu/business/tech/telco/telenor-to-have-several-hundred-5g-bases%C2%A0by-yearend
[44] 5G | 5G Ireland | Ireland's Best 5G Network - eir.ie

Country	Summary
	93% of the country. Network/infrastructure sharing agreements have been announced between WINDTRE and Fastweb, and TIM and Vodafone.[45]
Latvia	**Network operators offering 5G services: LMT, Tele2** *Not specified, assumed to be NSA* For their initial 5G deployment, both operators Tele2 and LMT relied on 3.5GHz spectrum.[46] Tele2 announced it will accelerate rollout to achieve 99 percent of the country's population within 3 years.[47]
Lithuania	**Network operators offering 5G services: Telia** *Not specified, assumed to be NSA* The first commercial 5G service has been launched by Telia. Using commercial 2100 MHz (DSS) and 3.5 GHz test frequencies, the operator’s 5G connection has been activated at 110 base stations.
Luxembourg	**Network operators offering 5G services: Orange, Tango, Post Luxembourg** *Not specified, assumed to be NSA* Three operators, Orange, Tango and Post use the 700 MHz and 3.6Ghz frequencies to operate their 5G networks.[48]
Malta	**Network operators offering 5G services: Melita, Epic** *Melita - not specified, assumed to be NSA* In May 2021, Melita launched Malta’s first 5G network nationwide. Melita 5G uses Band 1 and Band 78.[49] *Epic - not specified, assumed to be NSA*

[45] https://www.speedtest.net/insights/blog/5g-italy-q2-2021/
[46] https://developingtelecoms.com/telecom-business/market-reports-with-buddecom/11633-latvian-regulator-approves-spectrum-sharing-to-facilitate-5g-deployment.html?utm_source=related_articles&utm_medium=website&utm_campaign=related_articles_click
[47] https://developingtelecoms.com/telecom-technology/wireless-networks/12238-tele2-latvia-to-boost-5g-network.html
[48] https://smc.gouvernement.lu/fr/actualites.gouvernement+fr+actualites+toutes_actualites+communiques+2020+07-juillet+22-resultats-5g.html
https://business.post.lu/particuliers/mobile/5g
[49] https://www.melita.com/help/mobile/5g/which-frequency-bands-does-5g-use/

Country	Summary
	Epic has become the second telecoms company in the country to launch 5G services[50] with Ericsson selected as its exclusive 5G radio access network (RAN) provider.[51]
Netherlands	**Network operators offering 5G services: VodafoneZiggo, T-Mobile and KPN** *VodafoneZiggo - not specified, assumed to be NSA* In April 2020 launched its 5G network. In partnership with Ericsson, the operator implemented 5G services via its antennas and Dynamic Spectrum Sharing technology, using 800/1800/2100/2600 MHz bands. *T-Mobile - not specified, assumed to be NSA* In July 2020, the operator launched its initial 5G network based on its new 700 MHz spectrum band. The operator declares that 90% of the inhabitants of the Netherlands live in T-Mobile's 5G coverage area[52]. *KPN - not specified, assumed to be NSA* In July 2020, the KPN launched its initial 5G network based on its new 700 MHz spectrum, similarly to T-Mobile.
Poland	**Network operators offering 5G services: Polkomtel, T-mobile, Orange and Play** *Polkomtel - not specified, assumed to be NSA* In May 2020, the operator launched the country’s first commercial 5G mobile network in the 2.6 GHz band. It covers over 13 million people and is available in each of the provinces in almost 400 cities[53]. *Orange Poland - not specified, assumed to be NSA* In July 2020, the operator launched 5G services using the 2.1 GHz band. *Play - not specified, assumed to be NSA* In June 2020, the operator launched its commercial 5G services using the 2.1 GHz band.

[50] https://5gobservatory.eu/epic-launches-5g-in-malta/
[51] https://www.ericsson.com/en/press-releases/2021/4/epic-partners-with-ericsson-to-enhance-its-network-and-prepare-malta-for-5g
[52] T-Mobile's 5G, fast and stable internet | T-Mobile
[53] Polkomtel Sp. z o.o. | About the Company (plus.pl)

Country	Summary
	T-mobile - not specified, assumed to be NSA The last operator to launch commercial service was T-Mobile using the 2100 MHz band.[54]
Portugal	**Network operators offering 5G services: NOS** *NOS - not specified, assumed to be NSA* NOS is first operator in Portugal to launch 5G, following the country’s spectrum auction in October 2021.[55] To operate its 5G service, the operator secured 100MHz in the 3.6GHz band and 2x10MHz in the 700MHz band.[56]
Romania	**Network operators offering 5G services: Vodafone, Digi, Orange** *Not specified, assumed to be NSA* Vodafone, Digi and Orange all launched their commercial 5G services between June and November 2019. ANCOM reports that commercial 5G services available today in Romania use the bands 3400 – 3800 MHz and, starting with 2021, the band 2100 MHz also.[57]
Slovakia	**Network operators offering 5G services: Slovak Telecom, Orange, and O2** *Slovak Telekom - not specified, assumed to be NSA* In December 2020, Slovak Telecom launched commercial 5G services utilising 15 MHz of frequencies in the 2.1 GHz band, in combination with LTE spectrum. *Orange - Not specified, assumed to be NSA* In May 2021, Orange launched its 5G network using 3.5 GHz spectrum and Massive MIMO equipment. *O2 – Not specified, assumed to be NSA* In September 2021, the operator announced 15 new sites with 5G signal availability in the west of the country, with the plan to cover 20% of Slovakia’s population with 5G services by the end of the year. The network will rely on Ericsson’s 5G technology.
Slovenia	**Network operators offering 5G services: Telekom Slovenije** *Telekom Slovenije - Not specified, assumed to be NSA*

[54] https://www.commsupdate.com/articles/2020/06/09/t-mobile-poland-switches-on-5g/
[55] https://www.nos.pt/institucional/EN/media/Documents/26_11_2021_NOS_LAUNCHES_5G.pdf
[56] https://telecoms.com/511959/5g-to-arrive-in-portugal-within-weeks-says-anacom-chief/
[57] https://infocentru.ancom.ro/en/5g-commercial-services/#1610545667815-05466d39-5b8e

Country	Summary
	In July 2020, Telekom Slovenije launched the first commercial 5G network in Slovenia. Ericsson announced that Telekom Slovenije is using its Radio Access Network (RAN) and Cloud Core solutions for its 5G commercial rollout. Ericsson also assisted with a software installation to existing Ericsson Radio System and packet core equipment, enabling spectrum sharing between 4G and 5G on 2.6 GHz FDD spectrum. At the moment, Telekom Slovenije’s 5G network covers 33% of mobile users nationwide.[58]
Spain	**Network operators offering 5G services: Vodafone Spain, Telefonica, Orange and MasMovil** *Vodafone Spain - Not specified, assumed to be NSA* In June 2019, Vodafone Spain launched its commercial 5G services at 3.7 GHz. In April 2021, its network was covering 50% of the population. *Telefonica- Not specified, assumed to be NSA* In September 2020, the operator announced the switch-on of its 5G network, which uses 3.5 GHz spectrum, alongside with reframed 1800 MHz and 2.1 GHz frequencies. Currently, the network covers 80% of the Spanish population[59]. *Orange - NSA* In September 2020, Orange Spain launched 5G mobile services using the 3.5 GHz band in specific parts of 5 cities (Madrid, Barcelona, Valencia, Seville and Malaga). In 2022, coverage is expected to reach 90% through a combination of NSA 5G architecture and Dynamic Spectrum Sharing technology. The Ericsson Radio System, delivering Massive MIMO, powers the 3.6 GHz 5G network in Madrid and Barcelona. Ericsson also supplies Orange Spain with a 5G evolved Packet Core to support the 5G New Radio non-standalone 5G network. *MasMovil - NSA* In September 2020, Grupo MasMovil became the fourth Spanish operator to launch 5G services. Besides its 80 megahertz of spectrum in the 3.5 GHz band, the operator entered into an agreement with Orange Spain which gives Masmovil access to Orange Spain’s entire 5G network thanks to a “virtual active sharing mode” until 2028.[60] The operator says it has expanded its 5G coverage to 133 new towns since September, achieving a 54% population coverage.[61]

[58] Telekom Slovenije’s 5G Network Upgraded (total-slovenia-news.com)
[59] Telefonica’s 5G network already reaches 80% of the Spanish population (rcrwireless.com)
[60] https://www.rcrwireless.com/20210907/5g/masmovil-5g-network-reaches-553-towns-cities-across-spain
[61] https://www.grupomasmovil.com/wp-content/uploads/2021/12/201220NP_Yoigo-ampliaci%C3%B3n-cobertura-5G.pdf

Country	Summary
Sweden	**Network operators offering 5G services: Tele2, Telia Sweden, Tre and Telenor** *Tele2 - Not specified, assumed to be NSA* In May 2020, Tele2 launched its 5G network using 80 MHz of the 3.6 GHz spectrum band. *Telia Sweden - Not specified, assumed to be NSA* In May 2020, Telia Sweden announced the activation of its 5G network in Stockholm, using its existing 700 MHz spectrum. *Tre - Not specified, assumed to be NSA* In June 2020, Tre Sweden announced the commercial launch of 5G services using frequencies in the 2.6 GHz band.[62] *Telenor - Not specified, assumed to be NSA* In October 2020, Telenor Sweden launched commercial 5G service with 80 MHz of spectrum in the 3.7 GHz band.[63] The operator expects to cover with its 5G network 99% of Sweden’s population by 2023 as part of its network sharing agreement with Telenor (“Net4Mobility” joint venture). [64]

2.1.2 Coverage of commercial 5G

Although the initial focus of earlier EU initiatives such as the 5G Action Plan was on stimulating and monitoring early 5G deployment, the EU Digital Decade initiative now brings a clear shift of attention to 5G coverage as more Member States launch commercial services. Good 5G coverage will drive the digital transformation in all sectors of the economy and society with 5G vertical services playing an important part.

The Commission’s first 5G coverage goal was the 5G Action Plan, announced in 2016. It said all urban areas and major terrestrial transport paths should have uninterrupted 5G coverage by 2025. In 2021, the Digital Decade communication set further specific targets for 5G coverage, saying all populated areas and main transport paths are to be covered by 5G by 2030. As a starting point, the Commission defines populated areas as the “percentage of all places where

[62] https://www.lightreading.com/5g/telia-tele2-and-three-trumpet-swedish-5g-launches/d/d-id/759904
[63] https://www.rcrwireless.com/20201030/5g/telenor-launches-5g-stockholm-targets-nationwide-coverage-by-2023
[64] https://www.5gradar.com/news/nokia-selected-by-net4mobility-for-5g-expansion-in-sweden

households are located, including remote areas”.[65] The definition is likely to be “refined” in the future to take into account the need for coverage of different 5G use cases and the evolving market needs.

According to data collected by the Commission in 2020, the baseline for 5G coverage in the EU was 14% of populated areas at the time when the Digital Decade announcement was first made in March 2020. For a breakdown by member state see the table below.

It is important to note that at the time the 2020 information in this table was produced, only half of the Member States had begun their 5G network deployment. This has improved significantly, and as of December 2021, all but one Member States have launched commercial 5G services.[66] Therefore to reflect the differences, where available, a new set of figures have been provided based on operator (and regulator) announcements of population coverage by the end of 2021 per Member State in the table below.[67] Finally, the estimated coverage figure for EU27 (**49%**) is based on the sum of total number of people covered in each country (computed based on the percentage of population covered, obtained from operator/regulator reports where data was available) divided by the total EU27 population.[6869] This figure can be contextualised based on the latest population coverage figure estimated by ETNO, although not directly comparable, the latter one also covering non-EU countries, e.g. UK, Switzerland, Norway, Iceland and Western Balkans (**62%** in Q3 2021).[70]

Table 2: 5G coverage (% of populated areas) by Member State, status quo

Country	Population coverage (2020)[71]	Population coverage (2021)	People covered (estimation 2021)	Note (2021 figure)
Austria	50%	55%	4,912,965	Reported by NRA.[72]
Belgium	4%	4%	462,642	No announcements regarding (population) coverage.[73] 2020 estimation reused.
Bulgaria	0%	0%	-	No coverage figures reported.

[65] SWD(2021) 247 final
Staff working document on the policy programme: a path to the digital decade: https://digital-strategy.ec.europa.eu/en/library/staff-working-document-policy-programme-path-digital-decade
[66] The first commercial 5G service has been launched in Lithuania in January 2022 at the time of this report publication, completing EU27 deployment in 2022
Source: Telia
[67] Updates compared to the baseline set by the estimates are reported (where data is available) per Member State in the table (operator announcements).
[68] The additional EU23 figure provided in the table reflects the share of population covered only taking into account countries where information was available.
[69] Population statistics for 2021 accessed via Eurostat
[70] Source: ETNO State of Digital 2022
[71] Source: EC based on Broadband coverage in Europe studies.
[72] Regulator (RTR) reports 55 per cent 5G population coverage in Q4 2020
Source: RTR
[73] Proximus ambition to reach 100% in the coming years.

Country	Population coverage (2020)[71]	Population coverage (2021)	People covered (estimation 2021)	Note (2021 figure)
Croatia	0%	34%	1,372,361	Reported by operator (Hrvatski Telekom).[74]
Cyprus	0%	70%	627,204	Announcement by operator (Cyta).[75]
Czechia	0%	10%	1,112,985	Announcement by operator (T-mobile).[76]
Denmark	80%	80%	4,672,036	Announcement by operator (TDC Net).[77]
Estonia	0%	47%	625,132	Announcement by operator (Telia).[78]
Finland	12%	76%	4,205,683	Reported by regulator.[79]
France	0%	42%	28,156,033	Reported by operator (Free).[80]
Germany	18%	90%	74,839,528	Reported by operator (Deutsche Telekom).[81]
Greece	0%	60%	6,409,528	Reported by operator (Cosmote).[82]
Hungary	7%	10%	953,616	Reported by operator (Magyar Telekom). [83]
Ireland	31%	70%	3,504,835	Reported by operator (eir). [84]
Italy	8%	40%	23,703,026	Reported by operator (Windtre).[85]
Lithuania	0%	0%	-	No coverage figures reported
Latvia	0%	0%	-	No coverage figures reported
Luxembourg	0%	20%	126,946	Announcement by operator (Orange).[86]

[74] Hrvatski Telekom's 5G network currently has an outdoor coverage of 34% of the population in the country. https://www.telekom.hu/about_us/press_room/press_releases/2021/june_8
[75] Cyta planned initial population coverage of 70%
[76] T-mobile reports population coverage of 10.4%, Vodafone over 20%.
[77] Denmark's TDC NET, completed nationwide (80% population coverage) 5G deployment in December 2020
Source: https://www.fiercewireless.com/operators/denmark-leads-mobile-experience-tutela
[78] Telia reports its 5G networks reaching most of the population and cities in October 2021. Figure reported reflects 14 cities covered in July 2021.
[79] 76% of the households according to Traficom
Source: https://www.traficom.fi/en/news/half-internet-usage-finns-travels-through-mobile-network-5g-networks-are-being-built-rapid
[80] 41.75% population coverage reported by Free
Source: https://www.iliad.fr/en/nos-reseaux/presence-en-france
[81] Deutsche Telekom announces 90% of German population with 5G at the end of 2021
Source: https://www.telekom.com/en/media/media-information/archive/turbo-for-fiber-and-5g-643014
[82] 60% nationwide population coverage by the end of 2021 according to Cosmote.
[83] 9.8% population coverage by Magyar Telekom.
[84]70% population covered by eir
[85] 40% of the population covered by Windtre
[86] According to Orange, in 2021, 5G will be deployed all over the country. Estimation is based on 2020 announcement of city of Luxembourg (share of population applied).

Country	Population coverage (2020)[71]	Population coverage (2021)	People covered (estimation 2021)	Note (2021 figure)
Malta	0%	80%	412,880	Announcement by operator (Melita).[87]
Netherlands	80%	90%	15,727,874	Announcement by operator (T-mobile). [88]
Poland	10%	40%	15,136,000	Announcement by operator (Polkomtel).[89]
Portugal	0%	0%	-	No coverage figures reported.
Romania	12%	12%	2,302,344	No coverage figures reported. 2020 estimation reused.
Slovakia	0%	20%	1,091,956	Reported by operator (O2).[90]
Slovenia	0%	32%	674,873	Reported by Operator (Telecom Slovenia).[91]
Spain	13%	51%	24,265,842	Reported by operator (Orange).[92]
Sweden	14%	16%	1,660,687	Reported by operator (Three).[93]
EU 23	N/A	51%	216,956,974	Calculation only taking into account countries where information was available.
EU 27	**14%**	**49%**	**As above**	

[87] Nationwide coverage reported by Melita
[88] At the end of October 2020, T-Mobile claimed that 90 per cent of the Dutch population lived within its 5G coverage area.
[89] 40% of population covered by Polkomtel
[90] O2 Slovakia’s launch is expected to have achieved 20% population coverage.
[91] Telecom Slovenia reports 32% coverage of 5G
[92] 51.2% population coverage reported by Orange.
[93] 16% population coverage by Three.

2.1.3 International developments

Although the 5G Observatory primarily tracks developments in EU countries, it also follows significant international developments in the 5G sector. It is important to note that most of the figures collected on the number of 5G base stations are provided by governments, but in some cases such as the USA and Japan, they are based on market research estimates. It is possible that some market-based estimates are not entirely up to date or accurate. However, they allow for a good overview of the state of 5G deployment internationally.

Globally, South Korea is the clear leader in 5G deployment. According to the country’s Communication Agency, it now has 162,099 5G base stations.[94] If we take into account the country’s population, this equals 319 people per one 5G base station. Following South Korea’s lead is China, which has now deployed 916,000 base stations. Despite China’s significant population size, this works out to 1531 people per base station. The EU ranks just ahead of the US, with 105,993 base stations. This works out to 4224 people per base station.

In terms of assigned 5G spectrum, the 3.6 GHz band has proven to be the most used 5G band globally. All four countries in this comparison have assigned this valuable mid-band spectrum. The 28 GHz band is also well adopted, and it has been assigned in South Korea, Japan, and the USA. In the EU the situation is a little more complex as each country assigns their own spectrum. However, most countries have assigned at least the 3.6 GHz band for 5G deployment, while only 7 EU MS have assigned the 26 GHz band for which the demand has been lowest so far. See the spectrum assignment chart in 2.2.3 to see the full breakdown on a country-by-country basis.

[94] Source: Korea Communications Agency https://en.yna.co.kr/view/AEN20210927001500320

Table 3: International developments – overview

	China[95]	South Korea[96]	Japan[97]	USA[98]	EU
5G Mode[6]	NSA/SA	NSA/SA	NSA[99]	NSA	NSA/SA
Approximate number of 5G base stations	916,000	162,000	50,000	50,000	112,000
Population	1,402,000,000	51,780,000	125,800,000	329,500,000	447,706,000
People per base station	1531	319	2516	6590	3988
5G target bands assigned	700 MHz 2.6 GHz 3.6 GHz	3.6 GHz 28 GHz	3.6 GHz 3.6 - 4.1 GHz 4.5 GHz 28 GHz	600 MHz 2.5 GHz 3.45 - 3.55GHz 3.5 GHz 3.7 - 3.98 GHz 24 GHz 28 GHz	700 MHz 3.6 GHz 26 GHz[100]

[95] Source: Global Times Jul 13, 2021: https://www.globaltimes.cn/page/202107/1228513.shtml
[96] Source: Korea Communications Agency https://en.yna.co.kr/view/AEN20210927001500320
[97] Source: 5G Observatory June 2021
[98] Source: International Business Strategies Inc. https://www.wsj.com/articles/u-s-vs-china-in-5g-the-battle-isnt-even-close-11604959200#refreshed
[99] KDDI due to launch SA at end of 2021: KDDI Presentation to 8th 5G Global Event, Oct 14-15 2021
[100] Note: Spectrum assignments differ by country. See spectrum assignment chart in 2.2.3 for full EU breakdown of assignments

				39 GHz 47 GHz	
Indicative 5G subscriber numbers[101]	**166 million** (China Mobile only; source: China Mobile Research Institute) **173 million** (source: Ericsson 2020)	**17 million** (source: 5G Forum, Korea)	**14.19 million** (source: japantimes)	**15.8 million** (in Dec 2020; source: Insider Intelligence) **14 million** (including Canada; source: Ericsson 2020)	**8 million** (source: Ericsson 2020)

2.1.4 5G Verticals (& trials)

2.1.4.1 Overview

Whereas previous generations of mobile technologies primarily focused on human communication, including voice, data, and the internet, 5G has the ability to provide services for a range of industries where mobile telecoms has so far had little purchase. Because 5G features low latency and high speeds, it is well suited to enter the so-called “vertical” markets such as industrial and agricultural automation, the automotive industry, transport and healthcare. Early in the development of 5G/IMT-2020, the ITU identified 5G as a “key driver” for industrial and societal changes.

The 3GPP standardisation body released the first 5G specification in 2017 (Release 15). After the release of Release 15, focus quickly turned to optimising 5G for vertical domains in Release 16, which is informally referred to as ‘5G Phase 2’.

In June 2020, Release 16 was published, focussing on the verticals’ needs. Enhancements were made to 5G System enablers for verticals including industrial automation, including time sensitive communication (TSC), Ultra Reliable and Low Latency Communication (URLLC) and Non-Public Networks (NPNs). Enhancements were also made to Cellular Internet of Things (CIoT) and support for 5G system Vehicle-to-Everything (V2X) communication.

[101] Sources for subscriber numbers: Ericsson 2020 = figures for this year given in Ericsson mobility Report June 2021 p34; China - Deng Wei, China Mobile Research Institute, Presentation to 8th 5G Global Event, Oct 14-15 2021; Korea - Prof. HyeonWoo LEE, DanKook Univ. Korea, Presentation to 8th 5G Global Event, Oct 14-15 2021; Japan - Figure from March 2021 given in this article: https://www.japantimes.co.jp/news/2021/07/19/business/tech/tv-airwave-5g/, USA - From https://www.emarketer.com/content/5g-us-mobile-network-users-overview-2021

2.1.4.2 5G verticals in the EU

With the announcement of the EU Digital Decade policy initiative, the EU Commission has put emphasis on the importance of the digital transformation of business. The communication outlines that 5G will play an important part in this transformation. It states, “digital technologies including 5G, the Internet of Things, edge computing, Artificial Intelligence, robotics and augmented reality will be at the core of new products, new manufacturing processes and new business models based on fair sharing of data in the data economy.”

In Europe, trials of 5G verticals have been encouraged through the 5G Public Private Partnership project (5G PPP) which is funded by European Union research funding grants totalling €700m matched by €3.5bn of private investment between 2014-2020.

Furthermore, the 5G-PPP Vertical Engagement Task Force (VTF) has been established to coordinate and monitor activities related to working with vertical sector. The vertical sectors considered by 5G-PPP VTF are:

- Automotive
- Manufacturing
- Media
- Energy
- E-Health
- Public safety
- Smart cities

2.1.4.3 5G vertical spectrum: Do we need dedicated spectrum?

The licensing model (or model***s***) needed for 5G verticals is on an ongoing debate in the spectrum management world.

Some stakeholders argue in favour of dedicated spectrum, but there are also arguments against this. The mobile industry association, the GSMA, has warned[102] that doing so runs a serious risk of fragmenting the already-scarce 5G spectrum. This makes it harder for operators to achieve contiguous blocs – which will then have a result in reduced speeds and quality of service (QoS). Dedicating spectrum to verticals may also result in under-utilisation of 5G frequencies, as those frequencies cannot be reallocated dynamically to accommodate fluctuations in traffic.

However, recently a trend has been appearing. An increasing number of countries are adopting a local licensing model for dedicated spectrum for 5G verticals. Germany was the first country to

[102] https://www.gsma.com/spectrum/resources/mobile-networks-for-verticals/

decide to reserve the 3700 – 3800 MHz to verticals. This may be because of the potential benefits for industrial companies, which account for about 20% of the country’s GDP.[103]

In total 10 EU countries have proposed or implemented a local licensing model. These countries are as follows:

- Austria
- Croatia
- Denmark
- Finland
- France
- Germany
- Netherlands
- Poland
- Portugal
- Sweden

Belgium and the Netherlands proposed a similar approach to Germany. Most recently, Sweden adopted a local licensing model in the 3.6 GHz and 26 GHz bands.[104] In a slightly different approach, France[105] has offered frequencies in the 2600 TDD MHz band to businesses. [106] The airport operator Hub One, for instance, has been granted a 10-year 4G and 5G license by the regulator in February 2020 to be used in Paris’s airports. Air France will also benefit from HubOne’s licence. [107]

In Asia, the notion of 5G private networks has some traction. In Japan[108] a significant number of major companies have already acquired a spectrum licence.[109] The country’s communications ministry started to issue licences for the deployment of local 5G networks in 3.7 GHz, 26 GHz and 28 GHz frequency bands as early as December 2019. In South Korea, the Ministry will offer 100 MHz in the 4.7 GHz band and 600 MHz in the 28 GHz band later this year for campus networks at a fee of up to USD 88 per block. [110]

In the US, the FCC is hoping that it’s three tier CBRS (Citizens Broadband Radio Service) will allow enterprises to deploy private 4G and 5G networks and verticals. Agricultural equipment

[103] https://www.statista.com/statistics/295519/germany-share-of-economic-sectors-in-gross-domestic-product/
[104] https://pts.se/sv/nyheter/radio/2021/pts-oppnar-for-tilldelning-av-lokala-tillstand-i-37-ghz--och-26-ghz-banden/
[105] https://www.policytracker.com/air-france-gets-access-to-spectrum-for-business-lte-and-hopes-for-harmonised-5g-in-c-band/
[106] https://www.policytracker.com/air-france-gets-access-to-spectrum-for-business-lte-and-hopes-for-harmonised-5g-in-c-band/
[107] https://www.policytracker.com/air-france-gets-access-to-spectrum-for-business-lte-and-hopes-for-harmonised-5g-in-c-band/
[108] https://www.policytracker.com/japan-awards-its-first-commercial-licences-for-local-5g/
[109] https://www.policytracker.com/japan-awards-its-first-commercial-licences-for-local-5g/
[110] https://www.policytracker.com/south-korea-to-allocate-local-5g-spectrum-for-the-first-time/

manufacturer John Deere has already announced plans to use its CBRS spectrum to install a private 5G network in its factories.[111]

Nevertheless, the vast majority of the countries who have already auctioned the 3.5 GHz band did not reserve frequencies for enterprises. In these markets, verticals will have to rely either on unlicensed spectrum, or secondary access to mobile spectrum. Unlicensed spectrum may prove to be successful for certain private network scenarios, but mission critical applications are wary of unlicensed spectrum, which could have severe interference issues from other users.

The 3.8 – 4.2 GHz band is starting to gain traction as a solution for the current inconsistent approach to dedicated 5G vertical spectrum. Japan was the first country to assign 3.8 – 4.2 GHz for 5G, followed by the UK which released[112] the band in 2019 exclusively for local private and shared networks. The European Radio Spectrum Policy Group (RSPG) has published a consultation recommending member states to explore the use of the 3.8 – 4.2 GHz band for 5G verticals.[113] Developments surrounding this band could have profound impacts on the development of 5G verticals.

2.1.4.4 Trends

The 5G Observatory has been tracking the announcements of 5G trials in Europe and Internationally since 2018. The initial purpose of this was to monitor progress toward the 5G Action Plan. However, as commercial 5G networks have now launched in almost all EU-27 countries and the EU Digital Decade has realigned policy priorities the 5G Observatory will now focus on vertical trials.

5G verticals are still in the early growth phase. 3GPP Release 16, which specifically focused on 5G vertical needs was only finalised in early 2020. Furthermore, Release 17, which will also introduce new features for 5G verticals, is still in development. Some industry stakeholders have referenced this as a potential reason for the slow development of 5G verticals, particularly when compared to the rollout of commercial 5G. Furthermore, the pandemic may have also contributed to delays.

5G verticals appear to be particularly developed in ports. Several countries have now extensively tested 5G vertical integration in ports and harbours. Notable examples include:

- **Germany**: The Hamburg Port Authority, Deutsche Telekom and Nokia have conducted an 18-month field test at the ‘smart seaport’ in Hamburg, Germany. This test focussed on the integration of 5G in traffic and infrastructure control.[114]

[111] https://www.fiercewireless.com/private-wireless/john-deere-foresees-private-5g-at-its-factories-worldwide
[112] https://www.policytracker.com/ofcom-makes-3-8-4-2-ghz-available-for-private-networks/
[113] https://www.policytracker.com/3-8-4-2-ghz-gains-momentum-after-rspg-backing/
[114] https://www.telekom.com/en/media/media-information/archive/port-of-hamburg-is-ready-for-5g-574536

- **Belgium**: Proximus and the Port of Antwerp have announced a 6-month trial of a private 5G network.[115]

- **Belgium**: Port of Zeebrugge and Citymesh have launched a private 5G network in the Port of Zeebrugge. In the first phase, this involved connectivity for tugboats, air pollution detectors and cameras and quay sensors.[116]

- **Estonia**: Tallinn, Telia, Ericsson and Intel have created a 5G test and exploration area in the Port of Tallinn. This trial enabled internet connectivity for commercial cruise ship passengers while in port.[117]

- **Spain**: Telefónica and APM Terminals have trialled 5G at the port of Barcelona. This test included connecting cranes, vehicles and people.[118]

5G verticals in other industries appear to be in an earlier stage. Various trials are taking place in the transport and automotive sector, although these are mostly early-stage tests and demonstrations. Examples include:

- **Germany**: Nokia and Deutsche Bahn are testing 5G for autonomous trains and rail operations.[119]

- **Norway**: Ericsson, Telia and the Norwegian University of Science and Technology have carried out a demonstration of a 5G autonomous ferry.[120]

Other notable recently announced 5G verticals include:

- Germany: Volkswagen and Nokia trial private 5G network at manufacturing plant.[121]

- Nokia to build private 5G network in Finnish goldmine.[122]

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[115] https://www.proximus.com/news/2020/20200205-Proximus-and-Port-of-Antwerp-are-preparing-for-the-port-s-digital-transformation-by-developing-a-private-5G-network-.html
[116] https://citymesh.com/en/news/port-of-zeebrugge-accelerates-innovation-by-investing-in-a-5g-network
[117] https://www.ericsson.com/en/cases/2017/5g-telia-tallink
[118] https://enterpriseiotinsights.com/20210311/channels/news/telefonica-apm-terminals-to-deploy-5g-and-c-v2x-port-of-barcelona?utm_campaign=20210311%20Enterprise%20IoT%20NewsletterThurs&utm_medium=email&utm_source=Eloqua
[119] https://www.nokia.com/about-us/news/releases/2019/12/12/nokia-wins-deutsche-bahn-tender-to-deliver-and-test-the-worlds-first-5g-based-network-for-automated-rail-operation/
[120] https://www.teliacompany.com/en/news/news-articles/2019/telia-tests-5g-powered-autonomous-vessels/
[121] https://5gobservatory.eu/volkswagen-and-nokia-trial-private-5g-network-at-manufacturing-plant/
[122] https://5gobservatory.eu/nokia-to-build-private-5g-network-in-finnish-goldmine/

From the verticals the 5G Observatory has been tracking, most appear to be occurring within private networks. See the private network subchapter for more on this (2.1.5), including country by country examples of private networks and their associated vertical trials.

There are, however, some verticals which will run on public networks. An example of this is both Deutsche Telekom[123] and Vodafone[124] Germany’s recent announcement of 5G plans for the BMW iX car. This integration allows drivers to use 5G connectivity in their cars.

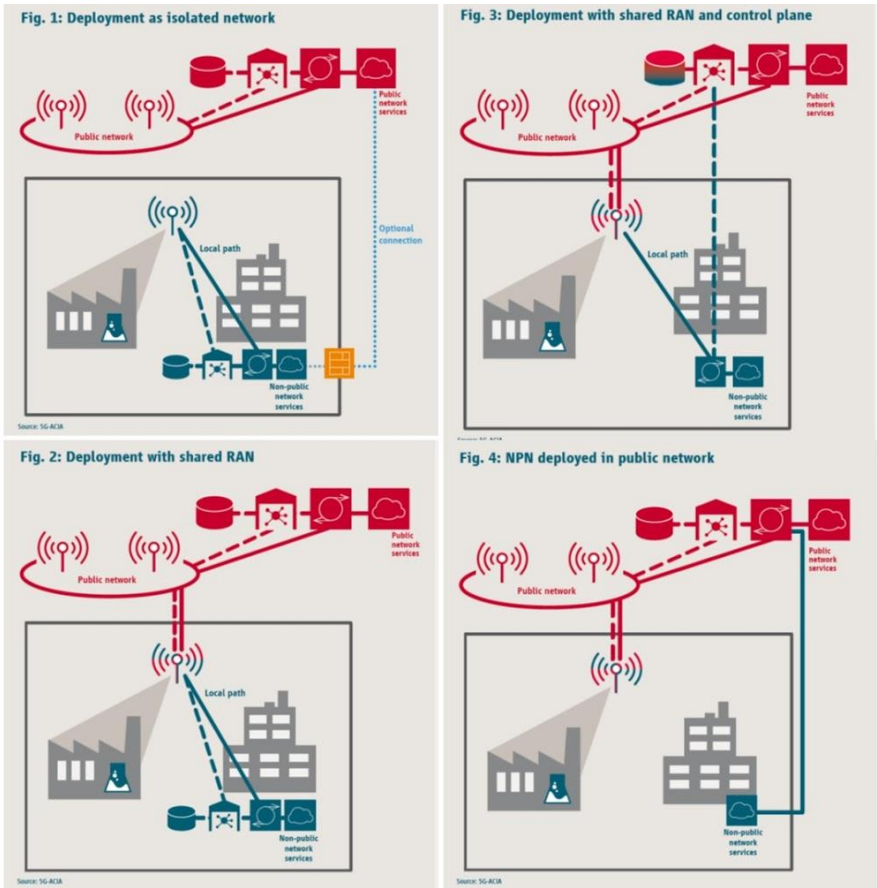
[123] https://www.telekom.com/en/media/media-information/archive/bmw-group-and-telekom-launch-in-car-5g-and-personal-esim-networking-options-635058?utm_source=TelecomTV&utm_campaign=08af352555-EMAIL_CAMPAIGN_2021_09_03_05_32&utm_medium=email&utm_term=0_6197c572c4-08af352555-162269693

[124] https://www.press.bmwgroup.com/global/article/detail/T0341435EN/bmw-group-and-vodafone-integrate-5g-and-personal-esim-networking-into-a-vehicle-for-the-first-time?language=en

2.1.5 5G private networks

The section on 5G private networks focuses on the EU countries that are deploying commercial private 5G networks. Private networks are best defined as those networks that are not typically utilised by consumers (for mobile voice and data services) but use network elements and resources to provide dedicated secure services to private enterprises such as factories, plants, large campuses, ports and airports. The architecture models can vary from completely private networks (all network elements owned and operated by the enterprise), through to a hybrid approach whereby a managed service provider or public operators provide access to their network infrastructure assets and/or spectrum. The diagram below has been extracted from the 5G Alliance for Connected Industries and Automation (5G-ACIA) which shows the different private cellular network architecture options that can be implemented in non-public network scenarios (primarily aimed at industrial networks).

Figure 3: Private cellular network architecture models



Source: 5G- ACIA

The roll out of private 5G networks is still in a relatively early growth phase that will be an important contributor to the continued productivity of Member States and adoption of new technologies for enterprises that will support the ongoing development of the 5G ecosystem.

There is particular interest by the Commission on which spectrum bands are used across different Member States for the deployment of private networks, noting that currently a limited set of frequencies are being used in some Member States. Notably, the decision by the regulator in Germany to allocate a dedicated 100 MHz portion in the 3.7 -3.8 GHz range for use by verticals enabling so-called 5G campus networks.

An update of the status and progress of private 5G network deployments is given for each Member State using the following structure:

- Identifies each private network per country based on published information
- Identifies which companies are deploying private networks including operators and vendors involved
- Identifies the sectors in which private 5G networks are being deployed
- The spectrum band being used where information is available

The list of private 5G networks in the table below is based on research of publicly available information. It is a non-exhaustive list and the Observatory team endeavour to obtain as much information on published private 5G network deployments as possible.

Country	Company /Entity	Operator	Equipment vendor	Overview
Austria	Automotive manufacturer Magna Steyr	A1 Austria	Nokia	In Austria, there was a deal struck by A1 and Nokia to provide wireless private networks to enterprises[125]. The partnership has already deployed private 5G networks at various locations and customers including at the automotive manufacturer site Magna Steyr, and at science and technology park in Klagenfurt south Austria. It is worth noting that, the spectrum band being used for its private networks has not been published but A1 holds 140 MHz of spectrum in the 3.4 – 3.8 GHz band which uses for 5G network and capacity expansion of the existing mobile network.
Austria	5G playground Carinthia	A1 Austria	Nokia	
Austria	Vienna airport	A1 Austria	Nokia	
Austria	Siemens renewable energy microgrid	A1 Austria	Nokia	
Belgium	Port of Antwerp	Proximus		As introduced in 2.1.4.4, there are a number of private 5G network deployments in Belgium that are being delivered by a number of different telecommunications players. Most notably, which has deployed a private 5G network at the Port of Antwerp to support a range of different operations from tugboat connectivity to drone deployments and surveillance. Proximus has secured spectrum in the 3.4 – 3.8 GHz band which it can use for its private 5G network deployments.
Belgium	Port of Zeebrugge		Nokia and Citymesh	5G-ready private wireless connectivity. Connectivity to more than 100 endpoints across the entire port operations.
Belgium	Brussels Airport		Nokia and Citymesh	The network commenced commercial operation in mid-2020 and is used for a range of applications including Beyond Visual Line of Sight drone operations. Citymesh has spectrum rights in the 3410 – 3510 MHz band

[125] Private Networks A1 Austria hands private 5G role to Nokia, LightReading September 20, https://www.lightreading.com/private-networks/a1-austria-hands-private-5g-role-to-nokia/d/d-id/765284

Country	Company /Entity	Operator	Equipment vendor	Overview
Croatia	5G private network solutions	Croatian Telecom	FER	Private 5G network solutions to be deployed in Rijeka, Split and Osijek to support solution in automation, robotics, edge and fog computing
Czech Republic	5G Campus network University of Ostrava	T-Mobile	Ericsson	Exploit and support experimental development of individual use cases of 5G technology and the Internet of Things in Industry 4.0
Czech Republic	Czech Institute of Informatics, Robotics and Cybernetics (CIIRC CVUT).	T-Mobile	Ericsson	5G campus network will enable scientists, students and industrial companies to develop innovative solutions for smart manufacturing and Industry 4.0.
Czech Republic	5G Campus network University of Prague (planned)	T-Mobile	Ericsson	5G standalone campus network at the Czech University of Agriculture to focus on IoT connectivity with an agriculture focus
Denmark	Grundfos (pump manufacturer).	TDC NET	Ericsson	The project is a trial-run, with a view to a broader 5G-enabled Industry 4.0 deployment across its factories.
Denmark	Maersk Port of Aarhus	Three		Currently a private 4G network upgradeable to 5G for enterprise services
Estonia	Thinnect OÜ		Nokia	5G Standalone network to enhance the Estonian Cyber Range’s Industry 4.0 capabilities.
Finland	Fortum Power and Heat (State owned energy company		EDZCOM	Traficom has granted the firm a 20 MHz portion of spectrum locally in the 2300 – 2320 MHz band at the site
Finland	KymiRing motor		Nokia, EDZCOM (Cellnex	Nokia is to implement an industrial-grade private 5G network at the KymiRing motor racing circuit in Finland. It will be completed in 2021 by EDZCOM, a European provider of edge connectivity solutions with particular expertise in broadcasting. It is part of Cellnex, which is probably better known for its towerco business.
Finland	Qualcomm, UROS	Elisa		Finnish network operator Elisa has deployed a private 5G network for a new-generation IoT hub developed by UROS and Qualcomm set to open this year in Oulu, Finland.

Country	Company /Entity	Operator	Equipment vendor	Overview
				The Innovation Centre is the first facility in Finland to utilise private 5G networking in IoT product development and validation. The network itself is already up and running and will serve all IoT ecosystem partners at the hub facility
Finland	Sandvik mining		Nokia	The network will enable fast, reliable and secure voice and video communications in a mining setting, which presents highly challenging deployment conditions. Its 5G capability will also be used for automated mining processes, enabling remote machine operations over 4K video links between deep underground and the surface control centre.
Finland	Konecranes		Nokia and Edzcom	Support digital transformation and research and development of the digitalised factory and port solutions.
Finland	Steveco shipping terminals in Kotka		Edzcom and Athonet	Two shipping terminals in Kotka to support full automation and business critical usage including secure, operational continuity and improve efficiency.
Finland	Agnico Eagle Finland Oy Kittilä mine		Nokia, Digita	Deployment a private 5G standalone network to support autonomous vehicles, positioning and mechanical operations. The network will also enhance operational efficiency and support the highest level of safety for teams working at the mine
France	TransDev (mobility)		Ericsson	Currently a 4G network operating in the 2575 -2595 MHz band in Rouen
France	Schnieder Electric	Orange		September 2020: Currently working on private 5G solution to support the energy company with its digital transformation
France	Lacroix	Orange	Ericsson	November 2020: French electronics manufacturer Lacroix Group has appointed Orange to deploy an indoor 5G network from Ericsson at a factory in France (Montrevault-sur-Evre) to run the rule over its value as a springboard for Industry 4.0, and as a foundation stone for its ‘flagship’ new ‘factory-of-the-future’. Orange will manage a virtualized network core, distributed between the premises of Orange and the Lacroix plant. The spectrum band utilised for the new 5G network is unconfirmed

Country	Company /Entity	Operator	Equipment vendor	Overview
France	ADP Group (Hub One) Air France		Ericsson	Acquired a 10-year 4G and 5G license by ARCEP in February 2020 to be used in Paris’ airports. Air France will also benefit from HubOne’s 40 MHz. The 4/5G network will serve a professional ecosystem of more than 120,000 people who work at the three Paris airports every day, across about 1,000 companies of differing sizes and sectors.
France	EDF		Thales and Ericsson	Acquired a 10-year licence in the 2.6 GHz TDD band (20 MHz)
France	Private 5G connectivity to enterprise networks in the PB5 La Défense building in Paris		Colt Technology Services, Icade, ADVA, Airspan Networks, Athonet, Accedian and Tibco	A collaboration led by Colt to bring benefits of private 5G networks to real estate using disaggregated architecture. This is a pilot to explore the varied use cases for the coworking space environment managed by the Imagin’Office. Use cases include creation of immersive experiences for the future workplace
Germany	BMW Group Leipzig plant.	T-Mobile	Ericsson	The campus network at the BMW Group plant in Leipzig is initially based on the LTE standard. In addition to the private campus network, the public network will transmit the same signal strength. This ensures a perfect connection even for terminal devices that are not allowed to transmit in the private network. Ericsson and Telekom are currently working together to further develop the functionalities of campus solutions based on 5G standalone. The development includes a 5G dual-slice solution that can also integrate the industry spectrum. The company bought spectrum in the 3.7-3.8 GHz band.
Germany	Bosch		Ericsson	Bosch acquired a 3.7—3.8 GHz local licence. The company is preparing to set up campus local area networks. Bosch started to build a private industrial 5G network at its semiconductor factory in Reutlingen, in Baden-Württemberg in Germany, to test for Industry 4.0 compatibility and network

Country	Company /Entity	Operator	Equipment vendor	Overview
				optimisation, along with industrial partners including ABB, Ericsson, Orange, and T-Systems.
Germany	Centre Connected Industry (CCI)	Deutsche Telekom	Ericsson	Switched on a 5G standalone private network in April 2020, at the Centre Connected Industry (CCI) at RWTH Aachen Campus. The end to end private network system is based on Ericsson‘s 5G standalone technology running in Deutsche Telekom’s 5G spectrum. The network is currently built as an indoor solution integrated with an autonomous logistics device to demonstrate possible industry use cases.
Germany	Deutsche Messe	Deutsche Telekom	Siemens	ebruary 2021: Trade fair operator Deutsche Messe secured a private 5G licence from German network agency BNetzA for the Hanover fairground, home to Germany’s flagship Industrie 4.0 event. Deutsche Telekom will set up “one of the largest 5G zones in Europe” and “Europe’s largest 5G exhibition centre”. The network will cover 1.4 million square metres, including all 30 halls and buildings at the site, as well as outdoor space
Germany	German electric microcar company e.GO Mobile AG (Aachen complex)	Vodafone	Ericsson	June 2019: In e.GO’s Factory 1, where the e.GO Life model is manufactured, an Ericsson Private Networks solution – spanning 5G Core and 5G New Radio solutions from Ericsson’s 5G Platform – will deliver secure and almost real-time data networking across the production chain, from digital material management to autonomous vehicle control.
Germany	Lufthansa, airline’s aircraft hangar in Hamburg airport	Vodafone	Nokia	March 2020: The private network covers an area of 8,500 square metres. Lufthansa acquired a 3.7—3.8 GHz local licence. The idea is the new private 5G network, offering “industrial grade” reliability, alongside ring-fenced latency and bandwidth performance, precludes customers from physically attending inspections; instead they are able to provide live high-definition video feeds of their engine overhauls in their own facilities to the Lufthansa Technik team in Hamburg.
Germany	Mercedes-Benz, Sindelfingen plant	Telefonica	Ericsson	Ericsson and Telefónica Germany built the network in the 220,000sq m complex and will hand over to Mercedes-Benz upon

Country	Company /Entity	Operator	Equipment vendor	Overview
				completion for operation. Initial applications will be factory automation and use to guide autonomous vehicles. The 730 million EUR Factory 56 facility is part of a 2.1 billion EUR “future-oriented” car plant and the administrative area in Sindelfingen, in Germany. The company claimed that the factory will have zero-carbon production, and a 25 percent jump in efficiency compared with the old assembly line at the site
Germany	Port of Hamburg	Deutsche Telekom	Nokia	February 2018: Deutsche Telekom and Nokia partnered in 5G network slicing trials on private deployment on site at the port of Hamburg
Germany	Rohde & Schwarz		Nokia	November 2020: The network is running in the 3.7-3.8 GHz band. Rohde & Schwarz has installed a private 5G network from Nokia at its plant in Teisnach, Germany. The network test company wants to run the rule over cellular-enabled Industry 4.0 applications in a dedicated 5G setup
Germany	Siemens		Qualcomm (5G test network)	ate 2019: Proof-of-concept project at the Siemens Automotive Test Centre in Nuremberg, Germany, demonstrating the first private 5G standalone (SA) network in a real industrial environment using the 3.7-3.8GHz band. The goal is to research the capabilities of 5G stand-alone networks for industrial applications. Siemens provided the industrial set-up (including the control systems and the IO devices) while Qualcomm provided the test network and equipment. Siemens has been reported in the press as having applied for local licences at six of its factory sites in German
Germany	Volkswagen			Volkswagen will start construction of its own 5G mobile networks in 122 factories in Germany in 2020. Construction of VW’s 5G SA network in Wolfsburg is complete and will be used to test a mix of requirements but also wireless upload of data to manufactured vehicles and intelligent networking of robots and wireless assembly tools

Country	Company /Entity	Operator	Equipment vendor	Overview
Germany	Porsche		Ericsson	Private 5G network deployed at Porsche’s production complex. The network is used to support production with networking, digitalisation and automation. Currently in a pilot phase.
Greece	Calpak[126] (solar thermal manufacturer)	COSMOTE	Ericsson	LTE based private campus network for smart manufacturing but is 5G enabled and can be upgraded to 5G when needed.
Hungary	Fixconn Komarom factory[127]	Vodafone	Ericsson	Support for manufacturing in the factory to improve efficiency and remove lots of cabling
Hungary	East-West Gate Intermodal Terminal (EWG) [128]	Vodafone	Huawei	Private 5G network built for internal communications and operation of technological devices including fully automated overhead cranes. The network aims to increase efficiency and improve working conditions in a large container terminal
Ireland	Irish Manufacturing Research	Vodafone	Ericsson	Vodafone has deployed what is being considered Ireland’s first private standalone (SA) 5G network at Irish Manufacturing Research’s (IMR) facility in Mullingar. IMR, an independent not-for-profit manufacturing and industrial energy efficiency research organization, will use the dedicated 5G network to develop and demonstrate smart manufacturing use cases in automated production lines and mobile robots, as well as augmented reality (AR) and virtual reality (VR) displays
Italy	Exor International	TIM	Athonet	Private 5G network deployed for factory automation and new digital services.
Netherlands	Shell, ABB and ExRobotics	KPN	Huawei	First industrial 5G-applications in Rotterdam harbour in the Netherlands. Thanks to 5G mobile networks manufacturing can be optimised, industrial maintenance can be better predicted and safety further improved. By using Ultra High Definition (UHD)-

[126] https://enterpriseiotinsights.com/20210215/channels/news/cosmote-ericsson-ptc-claim-first-lte-campus-network-in-greece
[127] https://bbj.hu/business/tech/telco/hungarys-1st-industrial-5g-private-network-goes-live-at-foxconns%C2%A0factory
[128] https://www.railwaypro.com/wp/5g-technology-to-be-deployed-at-east-west-intermodal/

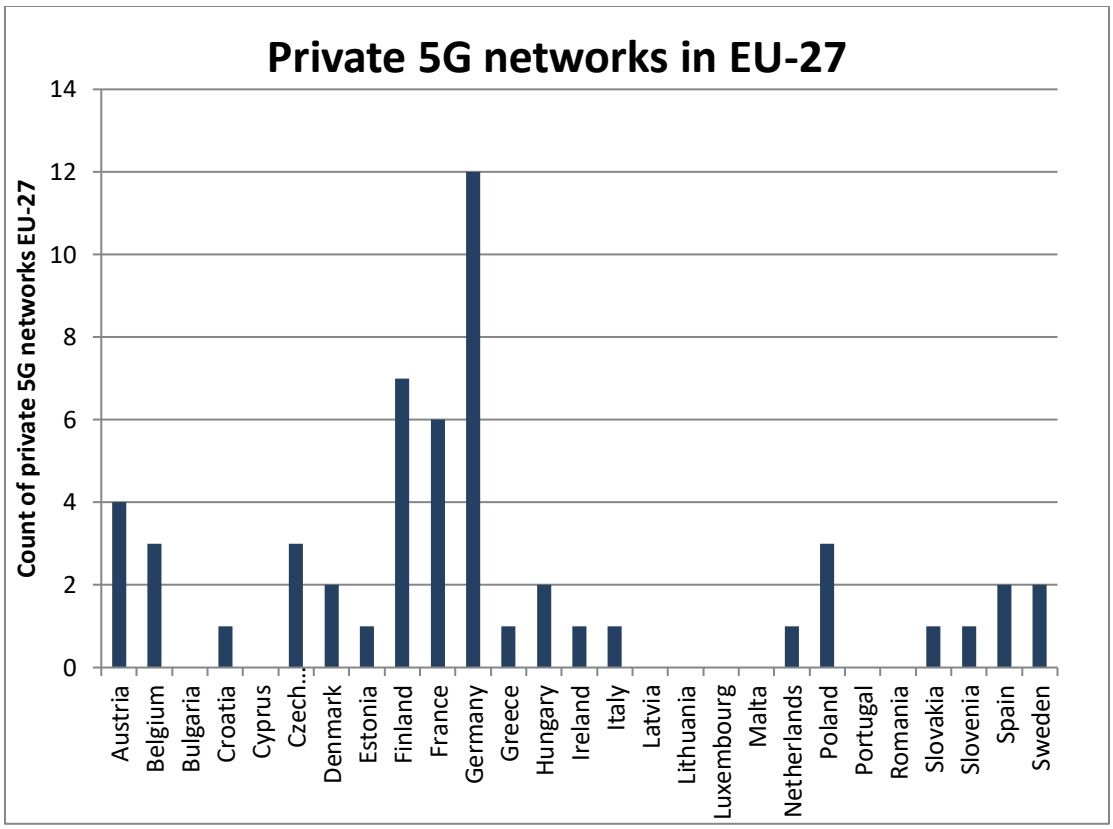
Country	Company /Entity	Operator	Equipment vendor	Overview
				cameras connected to 5G combined with machine learning algorithms, future maintenance can be better predicted.
Poland	Orange Polska Campus	Orange Polska	Ericsson	The operator says the network will be deployed in Ksawerów near Łódź, on a 6,000 square metre site of Miele's domestic appliances plant. The contract will last two years and the network will digitalise and automate the quality control process for manufacture products, as well as facilitate large-scale employee training programmes using virtual reality (VR).
Poland	PGE Systemy		Nokia	Nokia announced that Polish energy company PGE Systemy has chosen its 5G-ready, industrial-grade private wireless solution, following the successful trial of a 450 MHz proof of concept (PoC) network in operation since April 2019
Poland	Nokia factory in Bydgoszcz [129]	Orange Polska	Nokia	This private network is intended to help automate production processes, monitor device movements, including remote control of drones for monitoring containers. This is fully private network with no interconnection with Orange’s public network. The service is provided using spectrum in the 2600 MHz for which Orange Polska has a license.
Slovakia	CEIT (R&D centre)[130]	Slovak Telecom	Ericsson	Private 5G network deployed at the R&D centre in the Zilina University to support new solutions in Industry 4.0
Slovenia	5G connected factory – Iskratel production plant in Kranj	Telekom Slovenia	Iskratel	Support factory applications for industry 4.0 with industrial control, automation, intelligence and transformation
Spain	BASF	Masmovil	Cellnex, Nokia, Lenovo	November 2020: German chemicals company BASF and Spanish telecommunications infrastructure and services operator

[129] https://www.telecomtv.com/content/5g/nokia-turns-to-orange-for-private-wireless-network-in-poland-43209/
[130] https://www.telecompaper.com/news/slovak-telekom-launches-5g-network-in-zilina-bratislava--1365300

Country	Company /Entity	Operator	Equipment vendor	Overview
				Cellnex Telecom signed an agreement to install what Cellnex said will be the first private network based on 5G technology in the Spanish chemical industry.
Spain	FC Barcelona Stadium	Telefonica	Huawei	February 2019: Huawei collaborated with Telefónica to build standard dedicated 5G at the Nou Camp football stadium in Barcelona.
Sweden	Arlas Copco	Telenor	Ericsson, Fujitsu	October 2020: private 5G network in localised 3.7 GHz spectrum at Swedish tool manufacturer Arlas Copco’s factory in Stockholm. The radio gear and core network are from fellow Swede Ericsson; Japan-based IT firm Fujitsu is also engaged.
Sweden	Saab		Nokia, Vinnergi	December 2020: Aerospace and defence company Saab has deployed a factory-wide private 5G network at a manufacturing plant in Sweden. The facility in Linköping, in the south of the country, produces ‘aerostructures’, notably for Airbus and Boeing. The project is starting with LTE in the upper part of the 1.8 GHz band, which works for indoor coverage; it will migrate to 5G in the second quarter of 2021
Sweden	Skogforsk	Telia	Ericsson, Volvo, SCA and Biometria	Vehicles equipped with 5G are being used for safe remote control of forest machinery, in particular for control of timber yard vehicles mounted with cameras and other sensors.

A summary of the number of private 5G networks that have been found by the Observatory across the EU-27 countries is shown in the plot below.

Figure 4: Private 5G networks in EU 27



Source: European Commission/LS telcom

The table below presents a non-exhaustive list of 5G private networks outside the EU-27 countries.

Table 4: Examples of 5G private networks outside the EU-27

Country	Company/Entity	Operator	Equipment Vendor	Comments
China	Bluetron	China Telecom	ZTE	The network is being used to test out a new machine vision application. This combines the 5G network, with its network slicing capabilities, and mobile edge computers to provide enhanced machine vision analytics. The 5G network enables fast backhaul of the video streams to the MEC facilities in network slices that guarantee the latency, jitter and packet loss parameters.
China	West China Second University Hospital in Sichuan Province	China Mobile	Huawei	The 5G network, augmented with mobile edge computing facilities has been used to showcase a variety of new applications including a hospital management system that incorporates data about patients, waiting times, asset location, and live video camera feeds to provide a visual smart hospital management system.
China	Haier	China Mobile	Huawei	China Mobile, Huawei and Haier have completed a deployment of edge computing, 5G and machine vision into Haier’s manufacturing environment. With this solution top of the range stainless steel refrigerators are visually inspected, in near realtime, to screen out production defects
China	Yangquan Coal	China Mobile		China Mobile, and Yangquan Coal Group successfully built the first 5G underground coal mine network in China. With the help of this "super Gigabit uplink" underground network, supporting a peak uplink rate of 1100mbps, the network enables high definition audio and video communication, rapid data transmission and remote intelligent control of equipment.
Japan	Fujitsu	Japan	Fujitsu Telecom Networks	Japan’s first commercial private 5G radio station license from the Kanto Bureau of Telecommunications.

Country	Company/Entity	Operator	Equipment Vendor	Comments
				- Spectrum: 28.2 GHz to 28.3 GHz spectrum for 5G and 2.575 GHz to 2.595 GHz spectrum for LTE. - System configuration: 5G-NSA for data transmission, LTE for connection control between base stations and land mobile stations. About 28,000 square meters on the grounds of Fujitsu ShinKawasaki Technology Square.
Japan	Mitsubishi Electric C.			Allowed to test a local 5G system in a limited area using the 28.2 GHz-28.3 GHz spectrum band. Mitsubishi Electric said that it expects to launch demonstration tests at other business sites as well as establish new 5G infrastructure at its business sites and laboratories.
Japan	Toyota Production Engineering Corporation’s manufacturing sites		Nokia	5G ready private network to support IoT devices, equipment digitisation and visualisation. Nokia: connectivity piece–base stations, radios and core network equipment and Digital Automation Cloud for scalable operations and management. Japanese NS Solutions Corporation (ICT solution provider): wireless area design, license application support, system construction, and on-going maintenance and operation
Japan	OMRON Corporation	NTT DOCOMO	Nokia	Espoo, Finland – Nokia, NTT DOCOMO, INC. and OMRON Corporation have agreed to conduct joint field trials using 5G at their plants and other production sites. Aims to establish the feasibility of a layout-free production line using Autonomous Mobile Robots (AMRs). By taking advantage of 5G's tech, the solution will see AMRs automatically conveying components to the

Country	Company/Entity	Operator	Equipment Vendor	Comments
				exact spot where they are required based on communication with production line equipment.
Japan	Sony/Nuro Wireless 5G internet		TBC but interested vendors include Fujitsu, NEC, Sharp and Kyocera	Nuro Wireless 5G internet was set up to provide 5G connectivity for residential complexes in areas not covered by public 5G. It can also support businesses with specific needs such as factory automation
Russia	EVRAZ	Mobile TeleSystems PJSC (MTS)	Ericsson	Ericsson and Mobile TeleSystems PJSC (MTS) announced plans to jointly deploy a commercial LTE/5G-ready private network at steel and mining company EVRAZ’s digital Sheregeshskaya mine in south-central Russia. The private network will be built on the Ericsson Dedicated Networks solution.
South Korea	Naver Cloud		Naver Cloud	A private 5G network will be set up in a building near Seoul to test robots controlled by a cloud system to coexist with human workers. The aim is to use AI, robots and autonomous technology to establish a smart office using private 5G networks. Naver cloud will collaborate with Naver Labs that will bring the AI and robotic capability.
Taiwan	Inventec		Affirmed Networks (Microsoft), ASOCS	October 2020: Electronics manufacturer Inventec deployed a 5G standalone (5G SA) network at its plant in Taiwan, to bring automation and intelligence to its production line.
United Kingdom	AE Aerospace	EE (BT)		AE Aerospace, a manufacturer in England’s West Midlands, is the first UK SME to deploy a 5G private network, working with government-backed initiatives West Midlands 5G (WM5G), and Worcestershire 5G (W5G) and its technology partner BT. The 5G network is provided by BT’s mobile arm, EE.

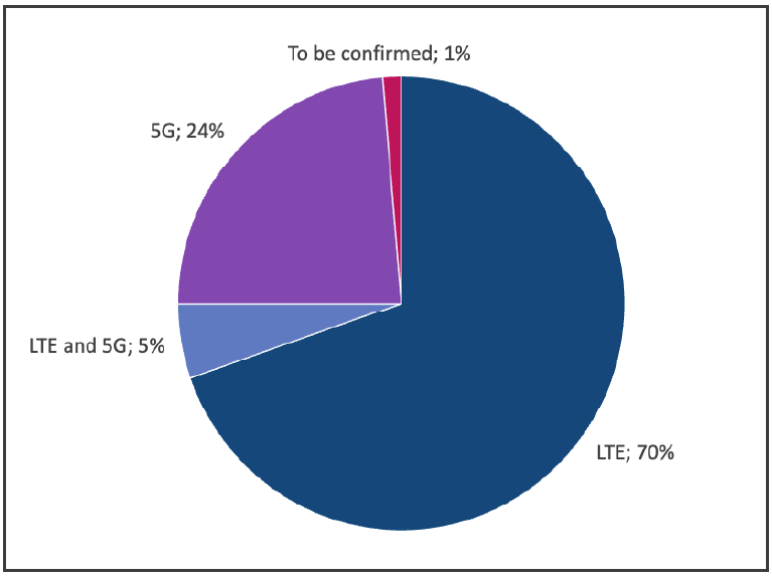
Country	Company/Entity	Operator	Equipment Vendor	Comments
				AE Aerospace operates a high precision engineering facility that produces parts for customers including Rolls Royce, Raytheon UK and Moog.
United Kingdom	Aerospace manufacturer Leonardo	Telefonica		Telefónica and Italy-based aerospace manufacturer Leonardo have announced a deal to collaborate on private 5G for Industry 4.0, including for the “high-pace” manufacturing of the “nextgeneration” Tempest combat aircraft system, a joint defence project between the UK, Italy, and Sweden.
United Kingdom	Centrica Storage Limited, the gas storage and processing unit of UK gas and electricity supplier Centrica.	Vodafone	Ericsson	Centrica Storage Limited, the gas storage and processing unit of UK gas and electricity supplier Centrica.
United Kingdom	Ford, electric vehicle production site in Essex	Vodafone		The project has received state funding as part of a GBP65 million (USD81 million) investment in 5G by the UK government. The facility is scheduled for completion in the autumn 2020. The aim is to reduce delays in manufacturing, increase bandwidth across the campus, improve security and reliability, and increase productivity.
United Kingdom	Port of Felixstowe	Three UK	Ericsson, Siemens	The port’s installation is part of the government’s 5G Trials and Testbeds Programme which is intended to drive investment and innovation in 5G and to support the development of new use cases and commercial deployment.
United Kingdom	Basingstoke and Deane Borough Council		Cellnex UK	Cellnex UK has been awarded a 10 year conraol to deliver a private 5G network to support local authority businesses providing 5G connectivity to develop, trial and introduce new projects and services. The network will provide both indoor and outdoor private 5G coverage.

Country	Company/Entity	Operator	Equipment Vendor	Comments
United States	Phillips 66 (US oil company)	AT&T	Accenture	Industrial LTE and 5G setup for low-latency refinery automation and analytics.
United States	Tideworks Technology		Nokia	Nokia announced an agreement with Tideworks Technology, a wholly owned subsidiary of Carrix, to deploy Nokia Digital Automation Cloud (DAC) at the Port of Seattle, Terminal 5. The objective is to deliver increases in efficiency, worker safety and terminal handling performance by reducing the complexity of port flow.
United States	Whirlpool	AT&T	Seegrid	December 2019: Whirlpool is deploying a private 5G network in one its Ohio factories to solve a major problem: Driverless vehicles inside the plant rely on Wi-Fi to navigate.
United States	Samsung	AT&T		AT&T and Samsung have deployed a 5G testbed at Samsung's Austin manufacturing facility as part of a "5G Innovation Zone". This provides a private 5G network that uses millimeter-wave (mmWave) spectrum, and also leverages LTE and Wi-Fi.
United States	Corning	Verizon		Verizon 5G Ultra-Wideband is being used at the Corning factory in Hickory North Carolina where the companies are working together to build the 5G factory of the future. The network is being used prove how 5G can enhance functions such as factory automation and quality assurance in one of the largest fibre optic cable manufacturing facilities in the world. Engineers from Verizon and Corning can use 5G to dramatically speed data collection, allow machines to communicate with each other in near real time, and wirelessly track and inspect inventory using 5G-connected cameras.

Country	Company/Entity	Operator	Equipment Vendor	Comments
United States	Department of Defence		Multiple vendors coordinated through National Spectrum Consortium	Expansive private 5G network deployments to support logistics, augmented reality and holograms across a range of military divisions including the marines. Another initiative has been introduced by DoD (2021) to support California’s first responders using private 5G. Aims of the initiative include providing autonomy to the National Guard during incidents and replace aging two-way radio voice networks. The system will use 3.5 GHz CBRS cellular radios.

The Global mobile Suppliers Association (GSA) has started tracking the deployment globally of private cellular networks which includes both 4G and 5G technology. Their last report from November 2021[131] indicated some high-level statistics of the number of deployments globally which is represented below to indicate the global scale of private mobile network deployments. Based on a figure of 775 private cellular network deployments worldwide, the GSA indicate that around 25% use 5G and LTE.

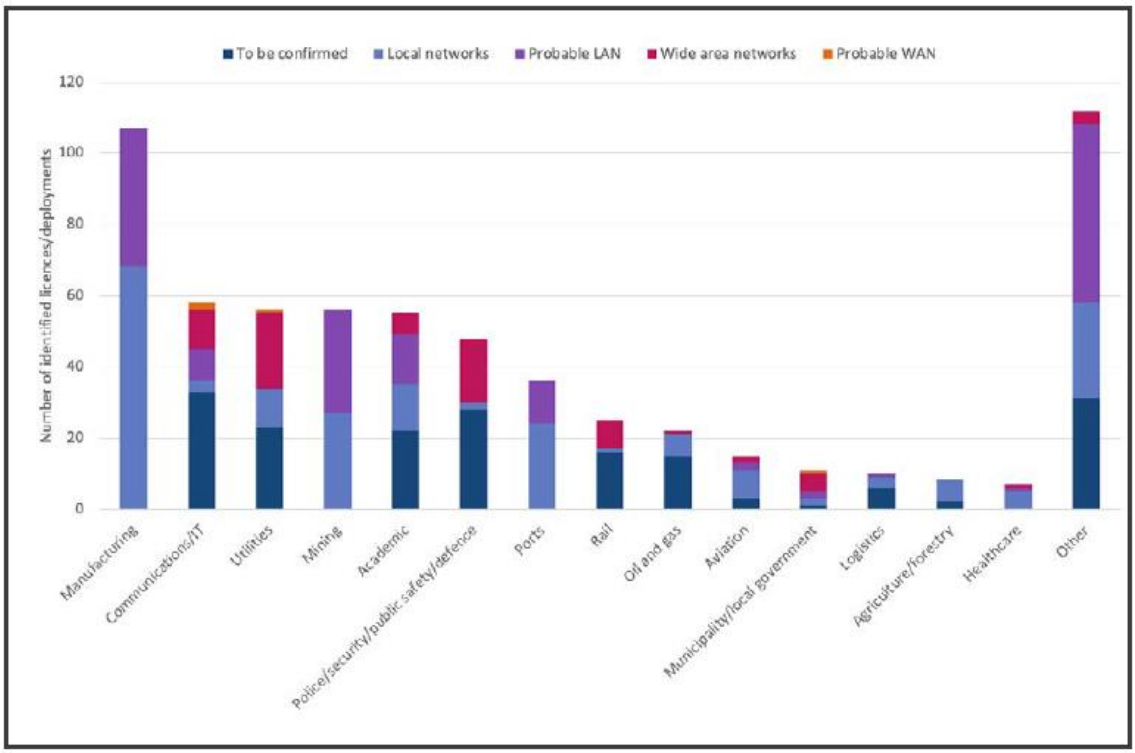
Figure 5: Proportion of private mobile network deployments using 5G



The GSA also highlights in its November report that the main industries deploying local area networks include rail (dominated by metro LTE deployments in China), manufacturing, mining and ports with other sectors such as aviation and healthcare also deploying networks. The representative set of data from the GSA is shown below for each of the sectors counted that have invested in private mobile networks. The figures include commercial roll outs and trials, those that hold suitable licences or in the process of being deployed. The figures are based number 775 organisations.

[131] Private Mobile Networks: Executive Summary, GSA, September 2021

Figure 6: Number of identified deployments across industrial sectors



2.1.6 Supply market trends (vendors): Major procurements, Open RAN, multivendor deployments

The telecommunications equipment supply market is evolving with the expected emergence of Open RAN offers alongside those of traditional vendors. Some governments and regulators are showing interest in these future offers, with the objective of further supporting a diversification of the telecommunications vendor supply chain. This trend originates from the technological capability to provide network functions through implementation of software functions running in the cloud and to provide open interfaces in addition to those already defined by 3GPP. It may provide for a more diverse supply ecosystem and is assumed to provide operators with more flexibility to implement innovation in their networks.

This section focuses on the major procurement announcements by mobile operators of which vendors have been selected for 5G roll outs, an overview of the recent Open RAN deployments and any impact this may have across the EU, in particular on growth of the wider vendor mix.

2.1.6.1 Major procurements

There have been a number of major procurements by large operators across EU countries in recent months. The following table shows which vendors have won contracts for the provision of 5G network builds across Member State countries.

Member State	Operator	Main 5G supplier	Date	Notes
Austria	A1 Telekom	Nokia		
	Drei	ZTE	2020	RAN
	Magenta Telekom			
Belgium	Proximus	Nokia and Ericsson	2020	Nokia RAN Ericsson Core
	Orange	Nokia and Ericsson	2020	Nokia RAN Ericsson Core
	Telenet	Nokia	2021	Nokia Core
Bulgaria	A1	Ericsson and Nokia		
	Telenor			
	Vivacom	Nokia	2021	Nokia Core
Croatia	A1	Ericsson		RAN and Core
	Hrvatski Telekom	Ericsson	2020	RAN
	Tele2	Nokia		
Cyprus	Cyta			
	Epic			
Czech Republic	Telefonica	Ericsson	2019	
	T-Mobile	Huawei		
	Vodafone			
Denmark	Hi3G Access	Ericsson	2018	
	TDC	Ericsson		
	Telenor	Ericsson and Nokia	2021	Ericsson Core Nokia RAN
	Telia	Nokia	2020	Nokia Core
Estonia	Telia	Ericsson		
	Elisa	Nokia	2021	
	Tele2	Nokia	2021	Core
Finland	Elisa	Ericsson and Nokia	2020	Ericsson RAN/Core Nokia RAN
	SYV	Nokia	2020	
	Telia	Nokia	2020	RAN
France	Free	Nokia	2020	
	Orange	Ericsson and Nokia	2020	RAN
	SFR	Nokia		
	Bouygues Telecom	Huawei	2018	Contracts due to expire 2028
Germany	Deutsche Telekom	Ericsson	2020	RAN
	Vodafone Germany	Ericsson		Ericsson Core

	Telefonica	Ericsson and Nokia		
Greece	Wind Hellas	Ericsson	2020	Core
	Cosmote	Ericsson	2020	EAN
Hungary	Magyar Telekom	Ericsson	2020	
	Vodafone Hungary			
Ireland	Eir	Ericsson	2019	Core
	Three Ireland	Ericsson	2020	
	Vodafone			
Italy	Iliad	Nokia	2020	
	Telecom Italia	Ericsson	2021	RAN and Core
	Vodafone	Huawei	2021	RAN
	Windtre	Ericsson	2018	Core
Latvia	LMT	Nokia	2019	RAN
	Tele2	Nokia	2021	Core
Lithuania	Tele2	Nokia	2021	Core
	Telia	Nokia	2020	Core
Luxembourg	Orange	Nokia		
	Post	Ericsson	2020	RAN and Core
	Tango	Nokia and Ericsson	2020	Ericsson Core Nokia RAN
Malta	Epic	Ericsson	2021	RAN
Netherlands	KPN	Ericsson	2020	Core
	T-Mobile			
	VodafoneZiggo	Ericsson	2020	
Poland	Orange			
	Play			
	Polkomtel (Plus)	Ericsson	2020	RAN and Core
Portugal	NOS	Nokia[132]		
Romania	Digi	Ericsson and Nokia	2020	
	Orange			
	Vodafone			
Slovakia	Orange	Nokia	2020	RAN
	Slovak Telecom	Ericsson	2020	RAN
Slovenia	A1	Ericsson		RAN and Core
	Telekom Slovenije	Ericsson	2020	RAN and Core
Spain	Masmovil	Ericsson	2021	Core
	Orange	Ericsson	2020	

[132] https://www.nokia.com/networks/5g/5g-contracts/

	Telefonica	Ericsson and Nokia	2021	
	Vodafone	Ericsson	2020	
Sweden	Telia	Ericsson and Nokia	2020	Nokia Core
	Tele2	Nokia	2021	
	Telenor	Ericsson	2018	Core
	Tre			

2.1.6.2 Open RAN overview

Open Radio Access Network (OpenRAN) is a network architecture with three driving components:

- Opening of interfaces to enable interoperability between equipment from different vendors enabling multi-vendor implementations and interoperability between different vendor equipment (X2, Xn, Open fronthaul interface)
- Virtualisation of RAN functions and implementation in (edge) clouds. This part is commonly known as vRAN
- Automation, through new interfaces enabling data collection and RAN management through the RAN Intelligent Controller (RIC), eventually using AI/ML techniques

There are two main initiatives working together to progress the Open RAN concept: Telecom Infra Project (TIP) via their OpenRAN project group and the O-RAN Alliance. The TIP OpenRAN project group is “*an initiative to define and build 2G, 3G and 4G RAN solutions based on general purpose, vendor-neutral hardware and software-defined technology*[133]”. There is also the OpenRAN 5G NR project group which focuses on 5G NR technology.

The O-RAN Alliance are developing industry specifications targeting i) production of interoperable equipment, or at least equipment that is capable of being interoperable; ii) reference implementation of RAN functions in clouds; and iii) RIC specifications.

More details of each group are provided below.

2.1.6.2.1 TIP – OpenRAN project group

The focus of the TIP OpenRAN project group is on deployment and execution ensuring the hardware from across the vendor ecosystem can interoperate. It supports trials, field testing and live deployments. It has developed the OpenRAN reference architecture (shown below) which demonstrates how the key components for both hardware and software fit together. It also shows

[133] Open RAN Terminology – Understanding the difference between Open RAN, OpenRAN, ORAN and more, Parallel Wireless, April 2020 www.parallelwireless.com/blog/open-ran-terminology- understanding-the-difference-between-open-ran-openran-oran-and-more/

between which components the different interfaces (backhaul, middlehaul and fronthaul) are placed within the network architecture.

Figure 7: OpenRAN reference architecture. Source: Telecominfraproject.com

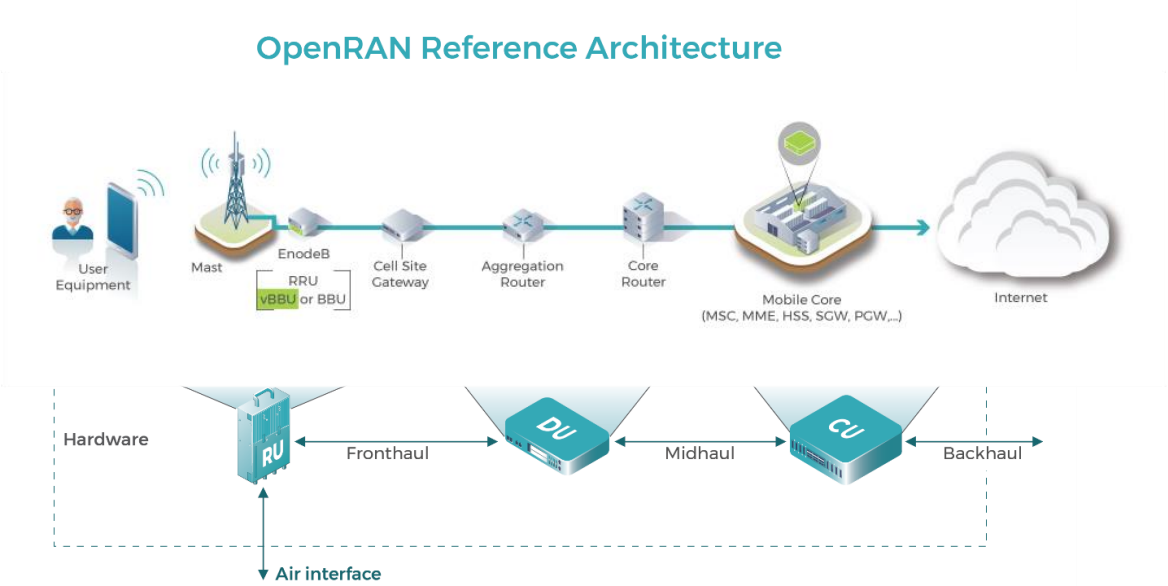


Figure 8: OpenRAN end to end architecture: Telecominfraproject.com

The key Open RAN principles include:

1. Disaggregation of RAN Hardware & Software on vendor neutral, 3GPP-based platforms
2. Open Interfaces – Implementations using open interface specifications between components (e.g. Radio Unit - RU/Centralised Unit - CU/Distributed Unit - DU/RAN Intelligent Controller - RIC) with vendor neutral hardware and software.
3. Multiple Architecture Options, including

    - An all-integrated RAN with disaggregation at SW and HW level
    - A split RAN with RU, BBU (DU/CU)
    - A split RAN with RU, DU and CU
        - A split RAN with integrated RU/DU, CU

4. Flexibility – Multi vendor solutions enabling a diverse ecosystem for the operators to choose best-of-breed options for their 2G/3G/4G and 5G deployments
5. Solutions implemented on either Bare Metal or Virtualized or Containerized Platforms
6. Innovation via Adoption of New Technologies (AI/ML, CI/CD…)
7. Diversification of the supply chain.

2.1.6.2.2 Open-RAN Alliance (O-RAN)

The Open RAN Alliance was founded by operators (DT, Orange, CMCC, AT&T, NTT DoCoMo) with the aim to promote and create a more software-focused and virtualised network environment. It is supported by several hardware vendors, including Intel, AMD, RISC, ARM, NVIDIA, HP, Lenovo, Dell, Nokia, Ericsson. O-RAN has more than 200 members, made up primarily from the members of the now merged C-RAN (CMCC) and X-RAN initiatives (AT&T).

The focus of the O-RAN Alliance is to transform the RAN industry towards “*Open, Intelligent, Virtualised and Fully Interoperable RAN*[134]”. The O-RAN Alliance has produced a reference architecture and specifications that vendors can use for trials and live deployments. One key difference of the O-RAN Alliance compared to TIP’s OpenRAN project group is the Alliance’s aim to build virtualisation on open hardware via the cloud with embedded AI-powered radio control. This is shown in the reference architecture below.

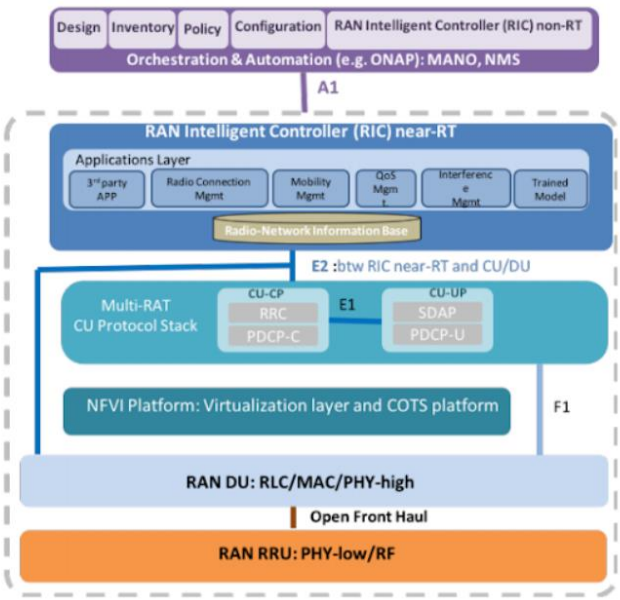


Figure 9: O-RAN Alliance reference architecture. Source: O-RAN Alliance

In addition, the O-RAN Alliance is more focused on 4G and 5G whereas TIP’s OpenRAN project group is focused on all mobile generations from 2G through to 5G.

[134] www.o-ran.org

2.1.6.2.3 Joint European Ecosystem

Signed by Deutsche Telekom, Orange, Telefónica and Vodafone agreed an MoU that has the following timescales for a standardised rollout of Open RAN network elements.

The signatories expect readiness and maturity of Open RAN for deployment in accordance with following definition of implementation phases. More detailed definition of phases, milestones and dates can be derived from the agreed activities listed in Article 4 of the MoU.

Table 5: Open RAN MoU implementation phases and releases

	Phase	Time Horizon
P0	Creation of the “Technical Priority Document”	Completed[135]
P1	Readiness for Pre-Commercial PoC (related to release R1)	From 2021
P2	Readiness for Initial Commercial Deployment in limited areas or for specific use cases such as rural, indoor or highway coverage (R1 release)	From 2021
P3	Readiness for Network Wide Rollout (R1 release)	From 2022

In November 2021, a report was published by Analysys Mason on behalf of the 5 operators having signed the Open RAN MoU highlighting possible priorities for Europe to accelerate the development and deployment of Open RAN. The report[136] ‘Building an Open RAN ecosystem for Europe’ compares the number of Open RAN players in Europe against the rest of the world. The report identifies five key policy recommendations to help Europe “*maintain a lead in the development and deployment of next generation mobile network*s”. The recommendations include:

- Ensure high-level political support for Open RAN
- Create a European roadmap for network innovation

[135] Technical Priority Document, Telefónica, https://www.telefonica.com/documents/737979/146026852/Open-RAN-Technical-Priorities-Executive-Summary.pdf/cdbf0310-4cfe-5c2f-2dfb-c68b8c8a8186
[136] https://www.vodafone.com/sites/default/files/2021-11/building-open-ran-ecosystem-europe.pdf

- Incentivise and support EU Open RAN development
- Promote European leadership in O-RAN standardisation
- Engage in international partnerships

2.1.6.2.4 Known uses of Open RAN

This section lists example deployments of Open RAN equipment globally, where it has been publicly announced. Upcoming deployment notices where there is a high probability of it being deployed are included.

Company	Supplier	Application	Date	Notes
Vodafone (Group)	Samsung	ORAN trials	2021	Ireland, Turkey, South Africa and Mozambique
Vodafone UK	Dell Technologies, NEC, Samsung, Wind River, Capgemini Engineering and Keysight Technologies	To deploy commercial Open RAN network in the UK	2021	Aim to extend 4G and 5G coverage across 2500 sites in the UK
Telefónica	NEC	Open RAN pre-commercial trials	2021	Spain, Germany, UK and Brazil.
Orange	Mavenir Hewlett Packard Enterprises Casa Systems Dell Technologies Xiaomi	Cloud 5G Open RAN Cloud 5G SA core network Cloud 5G SA Subscriber Data Management Servers supporting RAN CU/DU and Core	2021	
Deutsche Telekom	Dell, Fujitsu, Intel, Mavenir, NEC and Supermicro	mMIMO fronthaul Cloud native baseband	2021	O-RAN Town deployed in Neubrandenburg, Germany. Multi-vendor open RAN 4G and 5G services across 25 sites
TIM	JMA Wireless, Microelectronics Technology, Dell and Cisco	Open RAN trials	2021	Open, virtualised RAN in multiple locations across multiple operators, in both outdoor dense

				city networks and large-scale venues such as stadiums. These are pilots.
NTT DoCoMo	Fujitsu, NEC and Nokia	multi-vendor interoperability for its 4G and 5G base station, using ORAN Alliance specifications	2021 This is a pilot as well, using new frequency bands	
Rakuten (greenfield)		Cloud native solution	2020	
Dish (greenfield)	Altiostar, Mavenir and Fujitsu	OpenRAN software integration	2020	

In addition, Deloitte[137] has found 35 active Open RAN pilots across the globe. This is being driven by optimised Total Cost of Ownership, higher vendor flexibility and easier upgradeability. It is further noted that in some countries (including EU Member States) that certain vendors are no longer permitted for use in networks and this may accelerate adoption further.

Figure 10: OpenRAN deployments globally. Source: Deloitte

At this stage, most of the Open RAN deployments are pilots intended to validate the technology. The most advanced deployments are mostly targeting low-density rural zones where it is possible to assess the capabilities of the technology in a low traffic environment.

[137] The Open Future of Radio Access Networks Telecom Engineering Centre of Excellence (TEE), Deloitte, 2021

Out of more than 200 commercial 5G networks in the world, two are fully applying Open RAN principles (though with specific specifications): Dish and Rakuten.

2.1.6.2.5 Next steps for Open RAN

It is anticipated that Open RAN deployments will start to increase globally as the technology and capability matures. One research company, Dell’Oro predicts that total operator investment in OpenRAN including hardware, software and firmware (but excluding services) will reach $10 billion - $15 billion over the 2020 – 2025 period. However, this highly depends on the speed to market of the technology as market opportunities are shrinking as networks are being deployed with classical solutions from established vendors.

In Europe, a number of mobile operators have expressed interest and commitment, as exemplified by the pilot trials, to further investment and roll out of OpenRAN solutions which include 5G.

The Open RAN approach has also opened a debate between market players and policy makers concerning a number of areas where the technology has not yet proven its maturity at the moment. Some of these areas are the overall performance of Open RAN systems, the integration challenges with existing infrastructures, energy efficiency, cybersecurity resilience in a context of a larger attack surface and the possibility of the emergence of “gate keepers” at some levels in the supply chain (chips, cloud, etc). In that context, Vodafone has identified the need for high performance processors to reach the full Open RAN potential and has initiated an initiative in the field of micro-electronics components.

2.1.7 EMF developments related to 5G policy goals

5G can only be deployed if it meets limits designed to protect the public from exposure to Electromagnetic Fields (EMF). These limits are in place because high levels of EMF can be damaging to human health, causing cancers and affecting fertility.[138] The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has produced guidelines to protect the public from harmful effects associated with EMF. These guidelines at set at 50 times less than the level where there has been substantiated evidence of health damage[139]. A European Council Recommendation (1999/519/EC) [140] set EMF limits based on the ICNIRP guidelines.

The 2018 Electronic Communications Code[141] says protecting public health is “imperative” and urges Member States to take a consistent approach having “particular regard” to

[138] See *Health impact of 5G* (July 2021): a study for the European Parliament
[139] See ICNIRP GUIDELINES FOR LIMITING EXPOSURE TO ELECTROMAGNETIC FIELDS (100 kHz TO 300 GHz) (1998 then updated in 2020) p484 and 492
[140] See https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999H0519&from=EN
[141] See https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.321.01.0036.01.ENG&toc=OJ:L:2018:321:TOC (110)

Recommendation (1999/519/EC). However, these limits are not binding on Member States and there is inconsistency in how they are applied.

This is of concern for two reasons. Firstly, any country which sets very high limits creates a potential health risk, although we have found no examples of this. Secondly, setting very low limits makes it technically difficult or prohibitively expensive to roll out networks, so restricting the economic and social benefits of mobile technologies, including 5G.

For example, for nearly a decade, mobile operators in the city of Brussels complained about a radiation limit what was considerably lower than the ICNIRP limits and slowed the deployment of their services. This was amended in August this year and is now 14.5 V/m limit, significantly higher than the previous limit of 6 V/m, but still the most restrictive in Europe. The World Health Organisation (WHO) recommends a maximum radiation limit of 41.2 V/m. The mobile operator Proximus welcomed the change but said moving towards the WHO standards would “avoid limitations”[142].

2.1.7.1 Inconsistency in EMF limits

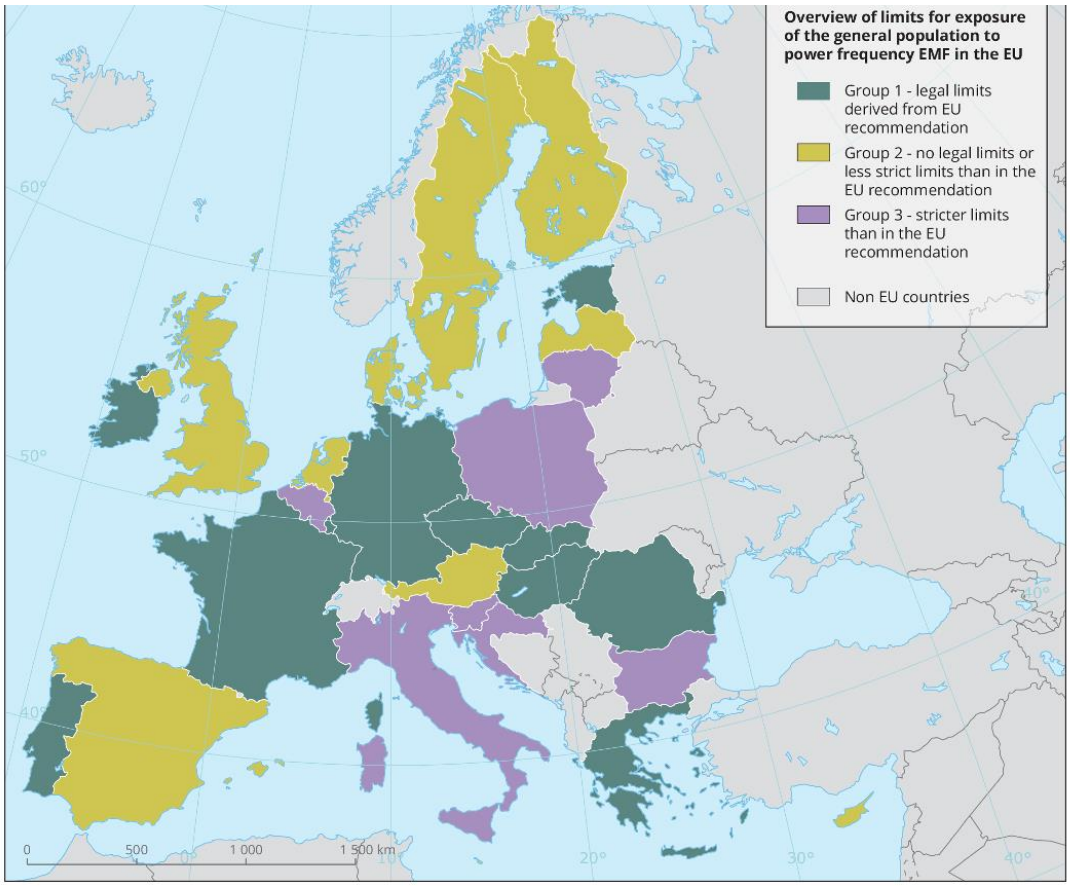
Two pieces of research have highlighted this inconsistency in approaches to EMF limits. The first was carried out by the National Institute for Public Health in the Netherlands in 2018[143]. It said there were three approaches to EMF in EU countries:

> **Group 1:** the EU recommendation has been transposed in binding national legislation or national policy.
> **Group 2:** national limits based on the EU recommendation or ICNIRP are not binding, there are more lenient limits or there is no regulation
> **Group 3:** stricter restrictions based on the precautionary principle or due to public pressure.

This is illustrated in the map below:

[142] See PolicyTracker Aug 13 2021 Brussels gets 5G-friendly emission limits for base stations
[143] Seehttps://www.rivm.nl/sites/default/files/2018-11/Comparison%20of%20international%20policies%20on%20electromagnetic%20fields%202018.pdf

Figure 11: 2018 grouping study of EMF limits in Member States



Source: National Institute for Public Health in the Netherlands (2018)

Work by IDATE and the GSMA published in the previous editions of the 5G Observatory give a similar picture in more detail and is shown in the table below.

As the study progresses we will continue to monitor the any changes in national EMF regulations, bearing in mind that these can have an impact on 5G-related EU policy goals, such as enhancing coverage. We note that currently the following countries all have limits which are stricter than the ICNIRP guidelines: Belgium, Bulgaria, Croatia, Greece, Italy, Lithuania and Luxembourg.

Table 6: Adoption of ICNIRP limits in the EU-27 Member States plus the UK

Countries	ICNIRP limits used?	Details
Austria	Yes	
Belgium	No	More restrictive than ICNIRP. Each region has its own limits.
Bulgaria	No	Public exposure limit of 0.1 W/m^2 (300 MHz to 30 GHz)
Croatia	No	Power density limits are 16% of the ICNIRP guidelines
Cyprus	Yes	ICNIRP limits adopted in 2004
Czech Republic	Yes	ICNIRP limits adopted in 2000
Denmark	Yes	
Estonia	Yes	ICNIRP limits adopted in 2002. No permit for ERP power <100W
Finland	Yes	
France	Yes	ICNIRP limits adopted in 2002
Germany	Yes	
Greece	No	60% of ICNIRP guidelines for base stations located less than 300 m from schools, hospitals... 70% of ICNIRP guidelines in other areas
Hungary	Yes	ICNIRP limits adopted in 2004
Italy	No	20 V/m as a general limit in open areas. 6 V/m inside buildings used for more than four hours a day
Ireland	Yes	
Latvia	Yes	
Lithuania	Yes	
Luxembourg	No	Limit at 3 V/m per operator and per antenna system. About 0.2% of ICNIRP limit above 2 GHz
Malta	Yes	
Netherlands	Yes	

Countries	ICNIRP limits used?	Details
Poland	Yes	ICNIRP limits adopted in 2020
Portugal	Yes	ICNIRP limits adopted in 2004
Romania	Yes	
Slovakia	Yes	ICNIRP limits adopted in 2007
Slovenia	Yes	For sensitive and protected areas limits are lower
Spain	Yes	ICNIRP limits adopted in 2001
Sweden	Yes	
UK	Yes	ICNIRP limits adopted 2000

Source: GSMA (2020) and IDATE DigiWorld

2.1.7.2 New EU rules on small cells

In June 2020 the European Commission adopted new rules[144] which make it easier to deploy the small cells often used in 5G networks and goes some way to harmonising EMF rules. The Implementing Regulation is binding on all Member States and means that small cells are exempt from individual town planning permits, if they fulfil certain technical and physical criteria.

The small cells must have an equivalent isotropic radiated power (EIRP) of less than 10 Watts, be positioned at least 2.2 metres off the ground and have a maximum volume of 30 litres with a minimal visual impact.[145]

The binding nature of this Regulation and the specifications regarding power levels may make it easier for operators to install very small 5G base stations which otherwise might have fallen foul of EMF regulations in those countries with stricter limits. However, the Regulation is “without prejudice to national measures regarding safety”[146], which may offer space for the continued application of stricter EMF limits.

[144] See https://digital-strategy.ec.europa.eu/en/news/commission-adopts-implementing-regulation-pave-way-high-capacity-5g-network-infrastructure
[145] See Implementing Regulation points 5, 6 and 8
[146] Ibid point 15

It will be easier to assess the impact of this Regulation by the end of the year, when Member States are required to make the first report to the Commission on how it has been applied.[147]

[147] Ibid Article 4

2.2 Policy / regulatory

This section provides a brief overview of the policy context at EU level for the deployment of 5G infrastructures and services. Focusing on the digital transformation (Digital Decade Policy Programme) set out by the EU within the 2030 timeline, the chapter concludes by highlighting the 5G specific targets set by the Digital Decade.

2.2.1 Public measures in the context of the Digital Decade

National administrations in the EU have taken measures to facilitate the introduction of 5G over the past 5 years which includes national 5G strategies[148] and completion of 5G spectrum assignments.

In addition to EU efforts to boost the deployment of 5G infrastructures and services across the Digital Single Market such as:

- the 5G Action Plan (launched 14 September 2016)
- framework conditions set by the European Electronic Communications Code (entered into force on 21 December 2018)
- the Connectivity toolbox will support Member States with 39 cases of best practices to facilitate the deployment of 5G infrastructure by reducing costs and the regulatory burden. Based on individual roadmaps for the implementation of the toolbox[149], all Member States will have to report on its implementation by 30 April 2022.

In March 2021, the European Commission set targets for the digital transformation of the bloc by 2030 in their Digital Decade announcement.[150] The digital targets for 2030 are as follows:

- A digitally skilled population and highly skilled digital professionals
    - at least 80% of those aged 16-74 have at least basic digital skills
    - at least 20 million employed information and communications technology (ICT) specialists are employed, with convergence between women and men
- Secure, efficient and sustainable digital infrastructure
    - all European households are covered by a Gigabit network, with all populated areas covered by 5G
    - the production of cutting-edge and sustainable semiconductors in the Union is at least 20% of world production in value

[148] An overview of these strategies can be found in the annex of previous quarterly report versions
[149] https://digital-strategy.ec.europa.eu/en/library/connectivity-toolbox-member-states-develop-and-share-roadmaps-toolbox-implementation
[150] Proposal for a Decision establishing the 2030 Policy Programme “Path to the Digital Decade” | Shaping Europe’s digital future (europa.eu)

- at least 10.000 climate neutral highly secure “edge nodes” are deployed in the Union, distributed in a way that guarantees access to data services with low latency (few milliseconds) wherever businesses are located
- by 2025, the Union has its first computer with quantum acceleration, paving the way for the Union to be at the cutting edge of quantum capabilities by 2030

- Digital transformation of businesses
  - Take-up by at least 75% of Union enterprises: cloud computing services; big data; artificial intelligence
  - more than 90% of Union Small and Medium Enterprises (‘SME’) reach at least a basic level of digital intensity
  - the Union grows the pipeline of its innovative scale ups and improves their access to finance, leading to at least doubling the number of unicorns

- Digitalisation of public services
  - 100% online accessible provision of key public services for Union citizens and businesses
  - 100% of Union citizens have access to their medical records (electronic health records (EHR))
  - at least 80% of Union citizens use a digital identification (ID) solution

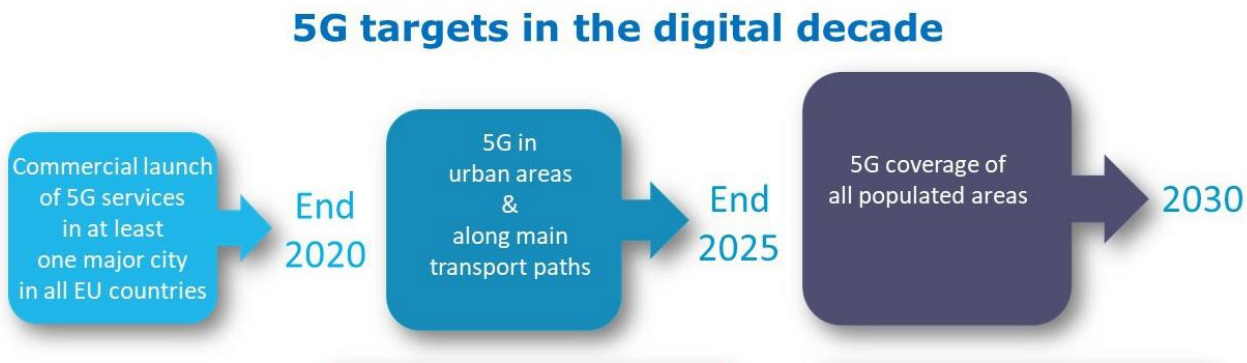
Following the entry into force of the Digital Decade Policy Programme:

- Within 6 months, the Commission will work with the Member States to develop trajectories that will help assess progress towards targets on an annual basis. Member States should then include these trajectories in their national strategic roadmaps alongside any other planned policies they intend to use.
- Within 1 year – the Commission will publish a yearly report on the ‘State of the Digital Decade’ that will monitor progress. The Commission will work closely with Member States in the five months leading up to this report to identify areas where progress is insufficient and agree on measures to ensure targets are achieved.
- In terms of progress monitoring tools, to ensure Member States are allowing progress towards the Digital Decade targets, the Commission intends to make use of peer review, Commission recommendations and possible further actions at EU level, as well as targeted dialogue.
- By 2026 the Commission expects to review the digital targets.

The development of 5G is an important part of the EU Digital Decade and it is expected that issues such as 5G rollout and as 5G verticals will be closely monitored. The Path to the Digital Decade needs to be approved by the other EU institutions and this is not expected to happen until spring next year at the earliest.[151]

[151] https://digital-strategy.ec.europa.eu/en/library/powerpoint-presentation-policy-programme-path-digital-decade

In terms of the level of ambition at EU level regarding the deployment of 5G infrastructures, as a complementary target to ensure that all European households are covered by a Gigabit network, by 2030, the EU aims to cover all populated areas by 5G.



Source: EC

2.2.2 5G corridors

This chapter introduces 5G corridors, which are projects designed to provide seamless 5G connectivity to vehicles even as they cross borders, thereby paving the way for autonomous driving on main road, train and maritime routes. To date, twelve "digital cross-border corridors" have been established to accommodate live tests of 5G for Cooperative Connected and Automated Mobility.

In the context of the 2030 Digital Compass Communication and ‘The European way for the Digital Decade’ outlining the European approach to a digitalised economy and society, the Commission is reviewing Europe’s 5G strategy as set out in the 5G Action Plan of 2016.

Europe has taken the lead in developing 5G industrial ecosystems with ambitious trial investments offering to enable market opportunities. Building 5G lead markets will be of key importance in this context. And, because industry R&I investments tend to relocate where markets are more advanced.

One area of high potential for such a lead market is 5G-based Connected and Automated Mobility (CAM). The Connecting Europe Facility Digital programme should support the rollout of 5G Corridors for CAM. This will unlock this ecosystem in Europe following a Strategic Deployment Agenda (SDA) developed by a broad range of stakeholders.[152]

[152] https://digital-strategy.ec.europa.eu/en/policies/5g-digital-decade

In order to prepare for the deployment of 5G cross-border corridors for CAM, the MSs signed, in March 2017 in Rome, a Letter of Intent (LoI) with the view to intensify cross-border cooperation for large-scale testing and pre-deployment. This agreement was preceded by bilateral initiatives memorandum of understanding, MoU) between Luxembourg, France and Germany, and among the Nordic countries (Norway, Finland, Sweden), and has been followed since then by a number of agreements between Spain and Portugal, between Bulgaria, Greece and Serbia, and between Estonia, Latvia, Lithuania and Poland over the “Via Baltica”, with an extension between Lithuania and Poland.[153] The more recent agreements include the “Figueres – Perpignan” cross-border corridor between France and Spain and a cross-border teleoperated transport for roads and maritime based on 5G connectivity in the ports of Antwerp (Belgium) and Vlissingen (Netherlands).[154] The table below presents the situation regarding the on-going initiatives.

Table 7: List of 5G cross-border corridors initiatives in the EU

5G Corridors	Political Commitment	H2020 projects (calls ICT-18 and ICT-53)
Metz-Merzig-Luxembourg FR-DE-LU	LoI between FR and DE in Sept. 2016. LU joined in Sept. 2017. Industry consultation in March 2018. Agreement for testbed signed.	**5G CROCO (**Nov. 2018): €17.2M Budget (€12.9M H2020 funded). Coord: CTTC (ES). Consortium: DT, PTLU, Orange PSA, Renault, Volkswagen, Volvo + Bosch, SANEF (FR Highways) Ericsson, Huawei, Nokia, i2Cat
Brenner Corridor IT-AT-DE	Italy and Tirol-Südtirol-Trentino (Euroregion) support to 5GCARMEN. No LoI signed yet.	**5GCARMEN** (Nov. 2018)**:** €18M budget (€ 15M H2020 funded). Consortium: DT, TIM, T-Mobile AT, BMW, FIAT Autostrade del Brennero (Brenner-Autobahn) NEC, Nokia, Qualcomm, CEA, IMEC. Support from IT Ministry of Transport, Euregio Tirol-SüdTirol-Trentino, Bavarian Road Administration.
Porto-Vigo, Evora-Merida PT-ES	LoI signed on Digital Day 2018, 10 April 2018	**5G-Mobix** (Nov. 2018)**:** a fraction of €27M budget (€21.4M H2020 funded) Coord: ERTICO (BE). Consortium: Cosmote, KPN, Telefonica, Turkcell, Ford Otomotiv, National Electric Vehicle Sweden, Auto-Estradas Norte Litoral, Brisa, Ericsson, NSN, Nokia, Siemens, Fraunhofer, TNO, VTT

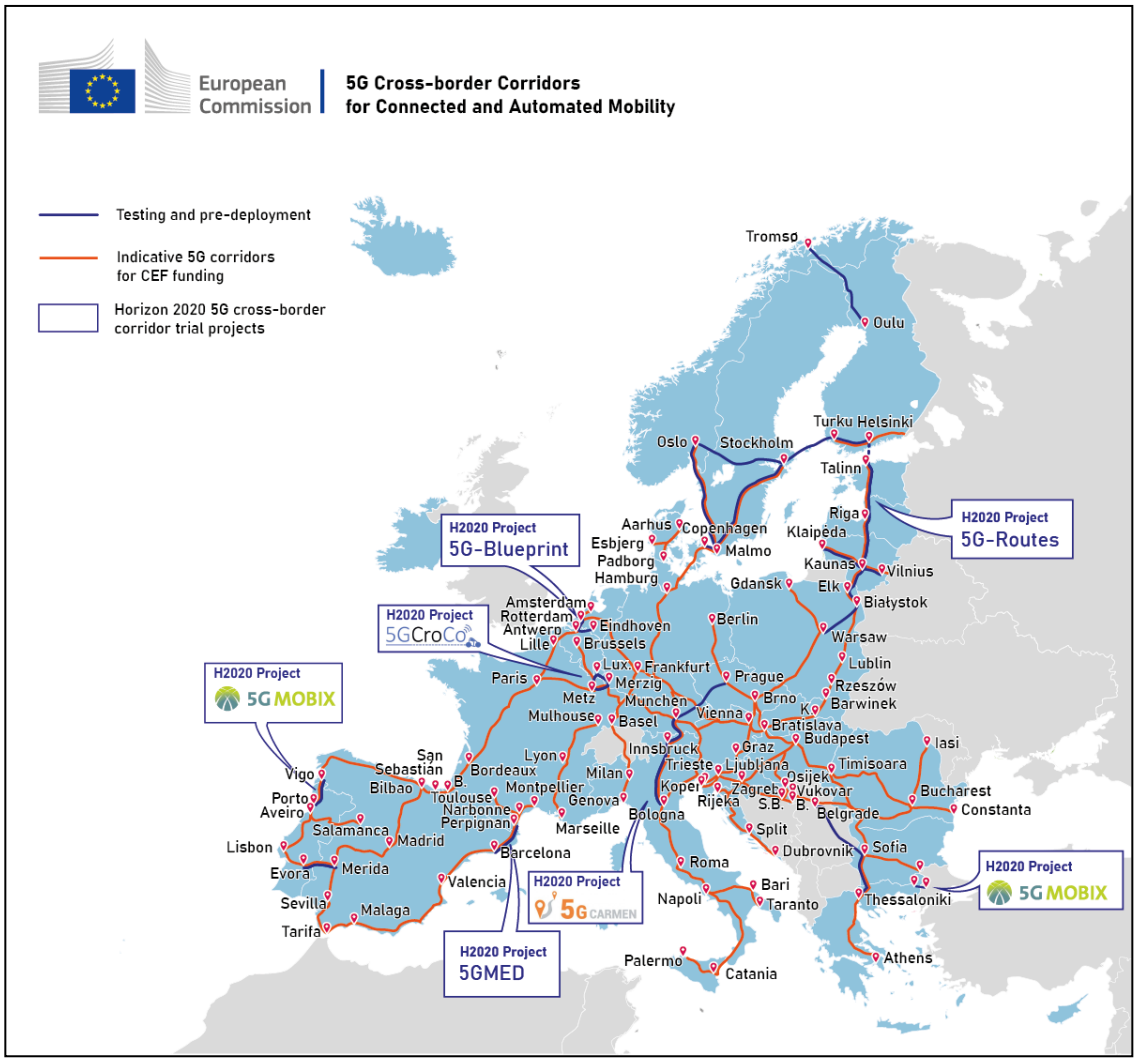
[153] https://digital-strategy.ec.europa.eu/en/policies/cross-border-corridors
[154] https://5g-ppp.eu/5g-blueprint/

5G Corridors	Political Commitment	H2020 projects (calls ICT-18 and ICT-53)
Antwerp-Rotterdam-North Sea (Vlissingen) BE-NL	MoU signed by Min. of Transport NL and Flanders. (BE), 7 May 2020	**5G-Blueprint** (Sept. 2020): € 11.7M (€ 9.2M funding) Trial limited to Vlissingen(NL)-Antwerpen (BE) (CAM+rail+maritime) KPN, Telenet Toyota, Swarco Ports of Antwerp & North Sea
Tallin-Riga–Kaunas-Vilnius EE-LV-LT +extension to Helsinki (ferry)	MoU signed by EE-LV-LT. in Sept. 2018 in Riga. Min. EE and LV + Traficom (FI) support to 5G-Routes (CAM, Rail, maritime)	**5G-Routes** (Sept. 2020): € 11.7M (€ 9.2M funding) LMT (LV), Telia EE Railway Cies of EE, LV Ericsson, Airbus, Swarco, Atos
LT-PL Via Baltica Kaunas-Warsaw, and further a national extension between Kaunas and Vilnius (LV)	LoI signed on 5 Sept. 2018. Goal is to cooperate in V2X, C-ITS, 4G LTE, LTE Advanced and 5G with the view to promote CAD. EE-LV-LT-PL consolidated MoU signed on 14 Sept. 2020.	*None*
CZ-Bavaria: Prague-Munich	MoU signed on 18 July 2019 in the perspective of CEF Digital.	
Thessaloniki, Sofia-Belgrade EL-BG-RS	Letter of Intent signed in June 2018 during Digital Assembly in Sofia. BG, EL and RS support to SEE-5G proposal	
Greece-Turkey (8 km segment across the border)	The Greek Ministry of Transport and the Greek Ministry for Digital policies, and the Turkish ICT Authority (BTK) have expressed support to the proposal from 5G-Mobix (see 3rd column)	**5G Mobix** (Nov. 2018)**:** a small fraction of €27M budget (€21.4M H2020 funded). Coord: ERTICO (BE). Consortium: Cosmote, KPN, Telefonica, Turkcell, Ford Otomotiv, National Electric Vehicle Sweden, Auto-Estradas Norte Litoral, Brisa, Ericsson, NSN, Nokia, Siemens, Fraunhofer, TNO, VTT
E8 "Aurora Borealis" NO-FI	C-ITS-TEN-T legacy. First 10km Aurora open in FI for testing since Nov. 2017. No LoI signed	National projects, with EU funding (CEF)
Nordic Way2 NO-SE-FI-DK	Follows-on Nordic Way 1, funded under C-ITS/CEF, which demonstrated that providing C-ITS services over cellular networks works. No LoI signed	National projects with EU funding (CEF)

5G Corridors	Political Commitment	H2020 projects (calls ICT-18 and ICT-53)
Barcelona-Perpignan, Santander-Biarritz ES-FR	MoU signed on 24 Sept 2020 between FR and ES	**5GMED** (Sept. 2020): € 15.7M (€ 11.9M funding) VOD ES, Hispasat, Cellnex FR SNCF Albertis Autopista (ES)

The map below presents an overview of the main public-private initiatives in Europe:

Figure 12: Map of 5G cross-border corridors initiatives



In addition to these initiatives, three Horizon 2020 projects were launched in November 2018 to conduct large-scale testing and trials of 5G connectivity for CAM over cross-border corridors, under the umbrella of 5G Public-Private Partnership (5G PPP). Benefiting from a nearly €50 million funding, for a combined total budget of €63 million[155], the three projects cover three 5G cross-border corridors: Metz-Merzig-Luxembourg (5GCroCo[156]), Porto-Vigo between Spain and Portugal (5G-Mobix[157]), and Bologna-Munich via the Brenner Path (5G-CARMEN[158]). In addition, CCAM use cases are tested in a strategic cross-border corridor located in the South-Eastern borders of Europe (between Greece – Turkey).

The development of 5G infrastructures along major transport paths will be further supported by the Connecting Europe Facility (CEF) Digital (2021-2027)[159] and the Resilience and Recovery Facility (RRF)[160]. The first CEF calls are expected to be launched by October-November 2021 (inception studies and early wave of deployment work).

[155] https://www.5g-mobix.com/newsandevents/pressreleases/working-together-on-5g-three-cross-border-and-corridor-projects-launched-at-ict2018
[156] https://5gcroco.eu/
[157] https://www.5g-mobix.com/
[158] https://5gcarmen.eu/
[159] https://digital-strategy.ec.europa.eu/en/activities/connecting-europe-facility
[160] https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en

2.2.3 5G Spectrum comparison between EU and other leading countries

In this section we compare 5G spectrum use by first introducing the “pioneer bands” identified at EU level for initial launch of 5G service, providing an overview of current spectrum assignment trends in the EU and contextualising these by introducing international developments. In terms of findings, overall, 58% of pioneer bands have been assigned in the EU. This is an increase of around 5% from October.

2.2.3.1 Overview of pioneer bands

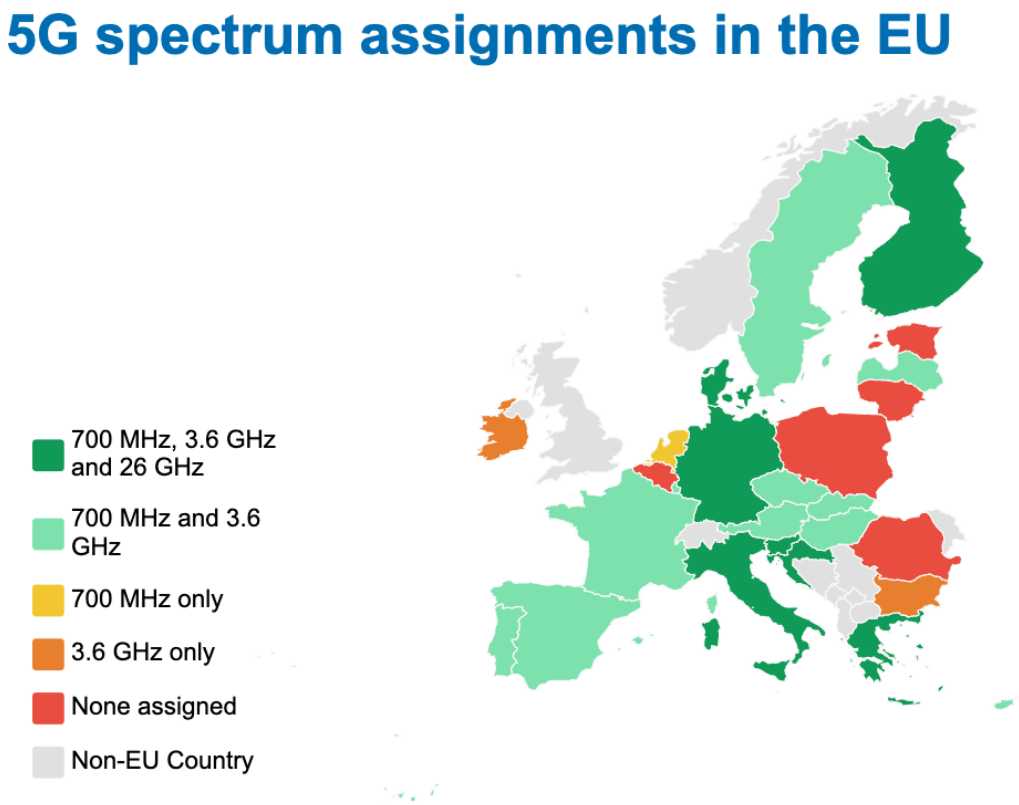
In 2016, with the release of the 5G Action Plan, the EU Commission proposed establishing a list of pioneer spectrum bands for the initial launch of 5G services. It proposed bands in three categories: below 1 GHz, between 1 GHz and 6 GHz and above 6 GHz.

The 5G pioneer bands identified at EU level are as follows:

- 700 MHz (703-733 MHz and 758-788 MHz)
- 3.6 GHz (3400-3800 MHz)
- 26 GHz (at least 1000 MHz within 24250-27500 MHz)

In the years following the release of the 5G Action Plan, the Commission successfully harmonised frequencies in these bands. The 26 GHz band was the final band to be harmonised. This occurred in May 2019 with an Implementing Decision announced by the Commission. Although these three bands have been harmonised at an EU level, it is up to Member States to decide how and when to assign them.

2.2.3.2 EU Trends



Source: Regulator announcements and consortium’s own research

Since October, three notable spectrum auctions have taken place. In Portugal, the 700 MHz band and the 3.6 GHz band were assigned in a national auction. In Latvia, the 700 MHz band was assigned in a national auction, and in Malta the 3.6 GHz band was assigned through a direct assignment. There have been no further awards in the 26 GHz band, although both Spain and Portugal have launched consultations about awarding the band. This has led to an overall increase of 5% in the total percentage of pioneer bands assigned in the EU. Now a total of 58% of pioneer bands have been assigned.

2.2.3.3 Pioneer bands assigned in the EU

Amongst Member States, the 3.6 GHz band has been most widely assigned. 21 out of 27 Member States have assigned this band. The second most popular band is the 700 MHz band, which has been assigned in 19 out of 27 Member States. The least popular band is the 26 GHz band, which has only been assigned in seven Member States. Finally, five Member States have failed to assign any of the pioneer bands.

Table 8: Pioneer bands assigned in the EU

Country	700 MHz	3.6 GHz	26 GHz
Austria	Yes	Yes	No
Belgium	No[161]	No[162]	No
Bulgaria	No	Yes	No
Croatia	Yes	Yes	Yes
Cyprus	Yes	Yes	No
Czechia	Yes	Yes	No
Denmark	Yes	Yes	Yes
Estonia	No	No	No
Finland	Yes	Yes	Yes
France	Yes	Yes	No
Germany	Yes	Yes	Yes[163]
Greece	Yes	Yes	Yes
Hungary	Yes	Yes	No
Ireland	No[164]	Yes	No
Italy	Yes[165]	Yes	Yes

[161] Note: 5G auction now scheduled for 2022,
162 Note: Temporary licenses have been granted for 5G services, https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/belgium-grants-temporary-5g-licenses-to-5-operators-8211-telecompaper-59455034
163 Note: Assigned on a first come first served basis with local licenses, not national auction, https://www.telecompaper.com/news/german-regulator-invites-applications-for-26-ghz-band-frequencies--1370648
164 Temporary covid-19 spectrum licenses in this band have been granted to operators, https://www.telecomtv.com/content/spectrum/two-irish-telcos-granted-coronavirus-licences-as-regulator-magics-up-new-spectrum-38341/
[165]The 700 MHz due to be cleared up in 2022.
Latest news source: https://tech.everyeye.it/notizie/switch-off-dvb-t2-sardegna-calendario-544155.html

Country	700 MHz	3.6 GHz	26 GHz
Latvia	Yes	Yes	No
Lithuania	No	No	No
Luxembourg	Yes	Yes	No
Malta	No	Yes	No
Netherlands	Yes	No	No
Poland	No	No	No
Portugal	Yes	Yes	No
Romania	No	No[166]	No
Slovakia	Yes	Yes	No
Slovenia	Yes	Yes	Yes
Spain	Yes	Yes	No
Sweden	Yes	Yes	No

There have been differences in how the pioneer bands are licensed, particularly in the 26 GHz band.

In Germany, for example, a part of the band is made available for local licensing. Sweden implemented a similar licensing scheme in the 3.7 GHz and 26 GHz bands. In Italy, the regulator opted for a “club licence” approach where auction winners could gain access to all the spectrum in any location it is not already used but must make their networks available to third parties on a wholesale basis[167].

166 Note: Note: Although an auction took place in Romania in November, only very few 5G pioneer frequencies were awarded. The regulator Ancom is planning a more comprehensive auction later this year, https://www.policytracker.com/romanian-5g-spectrum-auction-falls-short-of-expectations/

167 https://www.lepida.it/sites/default/files/u8/news/Bologna%20FM%205G%20martino%20vdist.pdf

In Greece and Finland, the 26 GHz band was assigned through nationwide licences sold at auction. However, both countries reserved some of the band for industrials applications and 5G verticals which remained unsold.[168]

Overall, 58.0% of pioneer bands have been assigned, with the following breakdown per band:

- 700 MHz: 70.4% % assigned and 29.6% not assigned.
- 3.6 GHz: 77.8% assigned, 22.2% not assigned.
- 26 GHz: 25.9% assigned, 74.1% not assigned

2.2.3.4 International trends

The three pioneer bands harmonised by the EU Commission roughly fit into the three categories of 5G frequencies often used by spectrum policy makers: mid-band, low-band, and high-band.

Although there are international discrepancies on which bands are used in each category, classifying the spectrum in this way allows for an easier international comparison on the state of 5G spectrum harmonisation and assignment.

Table 7: Categorising 5G spectrum awarded in major economies outside the EU

Country	Low-band (<1 GHz)	Mid-band (1 - 6 GHz)	High-band (>6 GHz)
China	Yes	Yes	No
South Korea	No	Yes	Yes
Japan	No	Yes	Yes
USA	Yes	Yes	Yes

[168] https://www.policytracker.com/greece-auctions-5g-spectrum-as-eu-clock-ticks-down/, https://www.policytracker.com/finland-concludes-26-ghz-auction-in-less-than-a-day/ , https://www.policytracker.com/finland-concludes-26-ghz-auction-in-less-than-a-day/

Table 8: Bands awarded in major economies outside of the EU

Country	Low-band (<1 GHz)	Mid-band (1 - 6 GHz)	High-band (>6 GHz)
China	700 MHz	2.6 GHz 3.6 GHz 4.9 GHz	-
South Korea	-	3.6 GHz	28 GHz
Japan	-	1.7 GHz 3.6 GHz 3.7 GHz 4 GHz 4.5 GHz	28 GHz
USA	600 MHz 850 MHz	2.5 GHz 3.45 - 3.55GHz 3.5 GHz 3.7 - 3.98 GHz	24 GHz 28 GHz 39 GHz 47 GHz

Internationally, mid-band 5G spectrum has been established as the workhorse band for 5G. It has been assigned in most major markets including China, South Korea, Japan and the USA. Low-band spectrum has proven to be slightly less popular, as both South Korea and Japan have yet to assign frequencies in this range. In fact, in South Korea’s initial 5G auction in 2016, the 700 MHz mid-band spectrum remained entirely unsold.[169]

A recent development in China however could indicate low-band spectrum becoming more popular. A new telecom player called China Broadcasting Network (CBN) recently struck a deal with China Mobile to begin deploying 5G using its 700 MHz spectrum.[170] This is notable as the country previously relied entirely on mid-band spectrum for its 5G deployment.

Initially, 5G frequencies in the high bands proved to be very popular. The US led the world in making the high bands available for 5G and Japan and South Korea quickly followed. However, it now appears that the band’s popularity may have peaked as indicated by the lack of 26 GHz assignments in many European countries.

[169] https://www.mobileworldlive.com/asia/asia-news/korea-auction-attracts-limited-interest-700mhz-goes-unsold

[170] https://developingtelecoms.com/telecom-technology/enterprise-ecosystems/11886-china-mobile-and-cbn-settle-700mhz-5g-plan.html

2.2.4 5G cybersecurity toolbox implementation

Cybersecurity has been an important priority in the context of 5G development The EU toolbox for 5G security is a set of robust and comprehensive measures for an EU coordinated approach to secure 5G networks. This chapter provides a brief overview of the progress and efforts undertaken by MS with the 5G Toolbox implementation, based on a report prepared by the NIS Cooperation Group, with the support of the Commission and ENISA.[171]

Since the publication of the last report, there have been some developments in the implementation of 5G security toolbox amongst Member States. In November, the Irish Government announced its plan[172]to use the EU 5G Security Toolbox as a framework for securing its 5G network. Also announced in December, Estonia’s State assembly passed the new 5G cybersecurity regulations in an amendment of the country’s Electronic Communications Act. The law will now need to be approved by the president.

In January 2020, the NIS Cooperation Group which is formed of representatives of Member States, the Commission and ENISA (European Union Agency for Cybersecurity), published the EU toolbox of risk-mitigating measures. On the same date, the Commission adopted a Communication which endorsed the measures outlined in the Toolbox and underlined the importance of their implementation.

The Toolbox addresses cybersecurity risks outlined in the previously published EU coordinated risk assessment report.[173] These risks can be largely categorised into four categories. These include:

- Local or global 5G network disruption (Availability);
- Spying on traffic/data in the 5G network infrastructure (Confidentiality);
- Modification or rerouting of the traffic/data in the 5G network infrastructure (Integrity and/or Confidentiality);
- Destruction or alteration of other digital infrastructures or information systems through the 5G networks (Integrity and/or Availability).

The Toolbox found a total of eight strategic measures that address these risks. In July 2020, the NIS Cooperation Group published a report that tracks Member States progress towards the EU Toolbox on 5G Security. Below you will find a summary of the eight strategic measures as well

[171] https://digital-strategy.ec.europa.eu/en/library/report-member-states-progress-implementing-eu-toolbox-5g-cybersecurity
[172] https://5gobservatory.eu/ireland-backs-eu-5g-security-toolbox/
[173] https://ec.europa.eu/commission/presscorner/detail/en/IP_19_6049

as an illustrative example from a Member State which was extracted from the progress report (if available):

- SM01 Strengthening the role of national authorities;
  - Example - Estonia: In May 2020, the Estonian Parliament approved an amendment to the Electronic Communications Act.[174] This amendment gives the government power to compel communication companies to provide information about the hardware and software used in their networks and to apply for authorisation to use the hardware and software of a network.

- SM02 Performing audits on operators and requiring information;
  - Example - Austria: Following a new telecom regulation, MNOs operating a 5G network have to comply with information security measures and have to maintain an Information Security Management System (ISMS).

- SM03 Assessing the risk profile of suppliers and applying restrictions for suppliers considered to be high risk - including necessary exclusions to effectively mitigate risks- for key assets;
  - Example - France: Key network assets are defined in the Order of 6 December 2019 and regulated as sensitive assets subject to control and authorisation before being rolled out. Those key assets include the radio access functions and most core network functions.

- SM04 Controlling the use of Managed Service Providers (MSPs) and equipment suppliers’ third line support;
  - Example - Finland: MNOs are required to ensure that, in a state of emergency, critical systems and their guidance, maintenance and control can be returned to Finland without delay. The regulator, Traficom also has the power to issue regulations relating to network management.

- SM05 Ensuring the diversity of suppliers for individual MNOs through appropriate multi-vendor strategies;
  - Example - Cyprus: The forthcoming regulatory framework will include guidelines for MNOs to develop and adopt appropriate multi-vendor strategies, using a risk-based approach.

- SM06 Strengthening the resilience at national level;
  - Example - Spain: Diversification objectives at national level will be considered in the national 5G Strategy.

[174] https://www.riigikogu.ee/en/sitting-reviews/riigikogu-amended-electronic-communications-act/

- SM07 Identifying key assets and fostering a diverse and sustainable 5G ecosystem in the EU;
- SM08 Maintaining and building diversity and EU capacities in future network technologies.

In addition, the report also outlined 11 technical measures and 10 targeted supporting actions that Member States can take.

The Commission called on the Member States to take concrete steps to implement these recommendations and prepare a report on their implementation. In July 2020, the NIS Cooperation Group published this report. It is important to note that this report was published on the 29th of January 2020, and developments may have taken place since then. Furthermore, this report is based entirely on contributions from Member States.

Notable findings in the report include:

- A large majority of Member States are in the process of significantly strengthening national regulator powers (SM01).
- The implementation of measures aimed at minimising the exposure to high-risk suppliers (SM03) is ongoing in many Member States, however, there is uncertainty surrounding the timeframe for adopting this as it is a complex and sensitive matter.
- A significant number of Member States appear to have yet to review existing practices and adopt measures to limit the types of activity and conditions under which MNOs are able to outsource particular functions (SM04).
- Most Member States have not yet established or communicated clear plans to effectively address existing situations of dependency on high-risk suppliers and prevent future dependencies (SM05 and SM06).

In conclusion, the report found that a large number of Member States have already taken concrete steps to implement the various strategic measures. However, it also found that work is still ongoing in the Member States on defining the content and scope of the measures. Going forward, it recommends that Member States should intensify efforts to exchange information amongst each other to facilitate Toolbox implementation.

Since the last publication of this report, there has been more progress on implementing 5G Security Toolbox measures from Member States.

In November, the Irish Government announced its plan[175] to use the EU 5G Security Toolbox as a framework for securing its 5G network. This will include legislation that will allow the Minister of the Environment, Climate and Communications to assess the risk profile of providers of electronic

[175] https://5gobservatory.eu/ireland-backs-eu-5g-security-toolbox/

communications network equipment and, if required, to designate certain vendors as being high risk.

The new legislation will be drafted in consultation with relevant Departments and Agencies, and a Regulatory Impact Assessment and consultation process will be conducted in early 2022.

In December, Estonia’s State assembly passed the new 5G cybersecurity regulations in an amendment of the country’s Electronic Communications Act. The law will now need to be approved by the president.

2.2.5 Next generation networks contribute to reaching Green Deal targets and addressing sustainability issues

Sustainability is another key topic accompanying 5G development. This chapter provides a brief overview of commitments taken up by the industry (mobile operators) to reduce emissions and the role of 5G in the context of the targets set by the Green Deal.

In its 2019 Green Deal Communication[176] the Commission highlights digital technologies as a critical enabler for attaining the sustainability goals set by the Green deal in many different sectors. In addition, the communication introduces the intention to explore measures to ensure that digital technologies such as artificial intelligence, 5G, cloud and edge computing and the internet of things can accelerate and maximise the impact of policies to deal with climate change and protect the environment.

The European Telecommunications Network Operators' Association (ETNO)[177] reports on initiatives undertaken by its members to reduce emissions and energy consumption, while ensuring the continuous development of new-generation networks. In fact, one of the specific measures to improve energy efficiency of telecom infrastructure and operations is the deployment of new mobile high-speed networks and particularly 5G technology, which is designed not only to increase network performance, but also to deliver increased energy efficiency.[178]

Improvements in energy efficiency linked with 5G deployments are explained on the one hand by 5G’s higher operational efficiency and on the other hand by its architecture which makes sharing of infrastructures more important to reduce costs. Along with 5G, fibre network deployments are also expected to deliver increased efficiency in terms of energy consumption.[179]

[176] https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf
[177] https://etno.eu/
[178] https://etno.eu/downloads/positionpapers/etno%20position%20paper_2030%20climate%20targets%20ec%20public%20consultation.pdf
[179] https://smarter2030.gesi.org/

In terms of technology, test pilots carried out by Ericsson in collaboration with Telefonica show that the 5G technology is up to 90% more efficient than 4G in terms of energy consumption per unit of traffic (W/Mbit/s).[180] Similarly, Vodafone has announced plans to deploy 1,500 low-power 5G units, after trials in Central London delivered a 43% reduction in energy consumption.[181] Although, overall short term energy usage for mobile operators is likely to go up[182], 5G includes smarter operations that invoke sleep modes designed to help break the historical link between new standards driving energy consumption upwards and making it the most energy-aware standard so far.[183]

In terms of climate action, in February 2019, the GSMA (comprising members from the largest mobile network operators in the world), set a milestone ambition for the mobile industry to reach net zero carbon emissions by 2050, at the latest.[184] Emissions reduction goals have been set in a phased approach to first reach carbon-neutral status before the more difficult and ambitious objective of net zero. In 2019, Verizon set to achieve net zero operational emissions by 2035 and committed to source or generate renewable energy equivalent to 50 percent of its annual electricity consumption by 2025. Telefónica expects to reach its target of zero net emissions in its four main markets by 2030, initially planned for 2050. This revision comes after achieving a 50% reduction in global CO2 emissions in 2019, fulfilling in advance the company's target for 2025[185]. Vodafone is committed to net zero for our own operations by 2030, and for our full carbon footprint by 2040.[186] On the road towards net zero targets operators’ actions can be grouped into energy-saving and efficiency measures on the one hand, and integration of energy sources not linked to harmful emissions on the other:

- **Optimising energy consumption (i.e. Energy intensity KPI):** Based on data from 31 networks in 28 countries, GSMA[187] found that 73% of the energy of the participating operators is consumed in the radio access network (RAN); the network core (13%), owned data centres (9%) and other operations (5%) account for the rest. In practice, energy efficiency initiatives reported by Vodafone include sourcing and deploying more efficient network equipment, gradually switching off the relatively less energy efficient 3G network and decommissioning legacy equipment in their core network.[188] Deutsche Telekom also tracks its energy efficiency KPI overtime and linked improvements to the

[180] https://www.ericsson.com/en/blog/3/2021/1/achieving-sustainability-with-energy-efficiency-in-5g-networks
[181] https://www.edie.net/news/6/Vodafone-plans-1-500-energy-efficient-5G-radios-after-trials-halve-energy-consumption/
[182] Based on ETNO, (referring to energy usage reported by operators in 2019).
[183] Source: ETNO
[184] more than a third of mobile operators by revenue: America Movil Group, Bharti Airtel Group, BT Group, Deutsche Telekom Group, Magyar Telekom Group, Orange Group, Proximus Group, Reliance Jio, Safaricom, Singtel Group, STC Group, Swisscom, TDC Group, Telefonica Group, Telia Group, Telstra Group, Telus, T-Mobile US, Verizon Wireless, Vodafone Group.
Source: https://www.gsma.com/betterfuture/wp-content/uploads/2021/04/Mobile-Net-Zero-State-of-the-Industry-on-Climate-Action.pdf
[185] https://www.telefonica.com/en/web/press-office/-/telefonica-brings-its-zero-emissions-target-forward-to-2030
[186] https://www.vodafone.com/sustainable-business/our-purpose-pillars/planet/net-zero-by-2040
[187] https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=60621137&file=300621-Going-Green-efficiency-mobile.pdf
[188] https://www.vodafone.com/news/press-release/100percent-renewables

use of new, more efficient network technology, systematic energy-saving measures and optimisations in own buildings as well as retirement of outdated, energy-intensive technology.[189]

- **Use of renewable sources:** nine operator groups are members of the global RE100 campaign which have made a commitment to go '100% renewable'. In addition, other operators have renewable electricity targets. Deutsche Telekom reports that its global network is already entirely green thanks to its use of electricity from renewable sources and aims for net-zero in-house emissions to be achieved by 2025. [190] Turkcell has made a commitment to exclusively rely on renewable sources by 2030.[191]. Telecom Italia (TIM) will cover around 20% of the company’s energy consumption through renewable sources through an agreement with ERG wind farms.[192] By mid- 2021, Vodafone’s European network will be powered by 100% renewable electricity.[193] Overall ETNO members report a 23% increase in the use of renewable energy sources.[194]

In its latest report, the GSMA provides an overview of targets and commitments taken up by operators:

Table 9: overview of targets and commitments by operators:

Mobile network operator	Science-based targets[195]	Carbon Neutral Target Year[196]	Net Zero Target Year[197]
A1 Telekom	1.5°C	2014	
America Movil	1.5°C		2050
AT&T	2°C	2035	
Airtel (Bharti)	Committed Aug 2019		2050
Bell (Canada)		2025	
BT (EE)	1.5°C		2045
Deutsche Telekom	1.5°C	2025	2040
Elisa	1.5°C	2020	
Far EasTone	2°C		
Iliad Group		2035	

[189] https://www.telekom.com/en/media/media-information/archive/deutsche-telekom-tightens-its-climate-targets-623582
[190] https://www.telekom.com/en/media/media-information/archive/deutsche-telekom-tightens-its-climate-targets-623582
[191] https://www.turkcell.com.tr/en/aboutus/corporate-social-responsibility/sustainability
[192] https://www.gruppotim.it/en/press-archive/corporate/2021/CS-TIM-ERG-en.html
[193] https://www.vodafone.com/news/press-release/vodafone-commits-to-net-zero-carbon-emissions-by-2040
[194] 2018 and 2019, and year-on-year growth ETNO Group level. Source: ETNO
[195] Science-based targets source: https://sciencebasedtargets.org/companies-taking-action/
[196] Carbon neutral target refers to reducing and offsetting carbon emissions from own operations (all Scope 1 and 2 emissions)
[197] Net zero refers to the criteria used by the UN Race To Zero campaign

Mobile network operator	Science-based targets[195]	Carbon Neutral Target Year[196]	Net Zero Target Year[197]
JT Global		2030	
KPN	1.5°C	2015	2040
Liberty Global	1.5°C		
LG Uplus		2030	
Magyar Telekom	1.5°C	2016	2050
MTN Group	1.5°C (pending)		2040 (pending)
NTT DOCOMO	<2°C		
Orange	Committed May 2018		2040
Proximus	<2°C	2016	2050
Reliance Jio	Committed Aug 2019		2050
Safaricom	<2°C	2050	2050
STC	Committed Mar 2020		2050
Singtel	<2°C		2050
SK Telecom	Committed Feb 2020	2050	
Swisscom	1.5°C	2020	2050
Taiwan Mobile	2°C		
TDC	Committed Jul 2019	2028	2050
Tele2	Committed Jan 2020	2020	
Telefónica	1.5°C		2025/2040[198]
Telenor Group	Committed Feb 2020	2030[199]	
Telia	1.5°C	2020	2030
Telstra	Committed Feb 2020	2020	2050
Telus	Committed Jan 2021	2030	2050
Verizon	Committed Aug 2019	2035	2040
Vodafone	1.5°C	2030	2040

Source: adapted from GSMA

Nevertheless, the biggest contribution the mobile sector can make to climate action, is to help other sectors of the economy reduce their carbon emissions through digitisation. Research

[198] 2025 in its four main markets. 2040 including all operations and value chain.
[199] Nordic operations

conducted by GSMA with the Carbon Trust in 2019 found that the mobile sector enables carbon reductions in other sectors which are 10 times larger to its own footprint, equivalent to approximately 4% of global emissions.[200][201]

According to Ericsson’s analysis of a European decarbonisation scenario,[202] connectivity is a necessity for climate solutions corresponding to approximately 550 million tons of CO2 (equivalent to 15 percent of the EU’s total annual emissions in 2017). By 2030, 5G technology use cases across 4 high-emitting sectors (i.e. transport, power, industry and buildings) are expected to create additional annual emissions savings 55–170 million tons of CO2 equal to taking one in seven of the EU cars off road (over 35 million cars). Sensor-driven efficiency improvements (for end users and industry), flexible working, improved truck utilisation are included among the illustrative use cases enabling incremental indirect abatement.

[200] https://www.gsma.com/betterfuture/enablement-effect
[201] GSMA continues reporting on the role of Digital and Mobile-Enabled Solutions in Addressing Climate Change e.g. in its 2021 report.
[202] https://www.ericsson.com/4ab228/assets/local/about-ericsson/sustainability-and-corporate-responsibility/environment/accelerate-5g-report-27102021.pdf

2.3 Research / innovation

The European Commission identified 5G opportunities early, establishing a public-private partnership on 5G (5G-PPP) in 2013 to accelerate research and innovation in 5G technology.[203] This chapter provides an overview of European funding programmes supporting 5G networks and related developments. Next a sample of projects and initiatives supporting the 5G ecosystem are presented at country level.

In the framework of Europe’s digital transformation by 2030, the Commission’s vision[204] for a human-centred, sustainable and prosperous digital future evolves around four key points: skills; government; infrastructures; businesses.

This seems even more relevant after that the COVID-19 pandemic shed light on the gaps on which the EU needs to take action urgently. For instance, the gap on investments to develop critical and disruptive technologies is particularly important, where it has been shown[205] that the public and private investment gap between the EU and countries such as US and China amounts to € 350-400 billion a year.

In this context, the Recovery and Resilience Facility[206] (the centrepiece of NextGenerationEU[207]) makes € 723.8 billion (in current prices) in loans (€ 385.8 billion) and grants (€ 338 billion) available to support reforms and investments undertaken by Member States. The aim is to mitigate the economic and social impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transitions.

Indeed, to benefit from the EU support for such transitions, it is foreseen[208] that each recovery and resilience national plan will have to include:

- A minimum of 37% of expenditure for climate investments and reforms
- A minimum of 20% of expenditure to foster the digital transition

[203] https://digital-strategy.ec.europa.eu/en/policies/5g
[204] Europe’s Digital Decade: digital targets for 2030 | European Commission (europa.eu)
[205] McKinsey, Shaping the digital transformation in Europe, September 2020
[206] Recovery and Resilience Facility | European Commission (europa.eu)
[207] Recovery plan for Europe | European Commission (europa.eu)
[208] Recovery and Resilience Facility | European Commission (europa.eu)

2.3.1 European funding programmes supporting 5G networks and related developments

This section aims to highlight the main funding opportunities at the EU level, giving also an overview of main projects and initiatives taking place at country level focusing on the development and support of 5G.

- **Recovery and Resilience Facility (RRF)**[209]: Entered into force in the 19th of February 2021, the RRF is the centrepiece of Europe’s recovery plan, NextGenerationEU. It guarantees €723.8 billion (in current prices) in loans (€385.8 billion) and grants (€338 billion) available to support reforms and investments undertaken by Member States. The aim is to mitigate the economic and social impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transitions. It will finance reforms and investments in Member States until 31 December 2026. To access the funding from the Facility, the national plans will be assessed by the Commission against the targets of a minimum of 20% of expenditure to foster the digital transitionA study by Deloitte estimates €18bn Funding linked to 5G and gigabit networks across the 20 National Recovery and Resilience Plans (NRRPs).[210]

- **Structural and investment Funds (ESIF)** [211]: The ESIF are jointly managed by the Commission and the EU countries, with the aim to invest in job creation and a sustainable and healthy European economy and environment. The ESIF mainly focus on the following 5 areas: research and innovation; digital technologies; supporting the low-carbon economy; sustainable management of natural resources; small businesses. Following the entry into force on the 1st of July 2021 of the 2021-2027 Cohesion policy legislative framework, the Commission adopted decisions on the breakdown of the EU budget allocations in coherence with different cohesion policy “goals”. One of the goals is the one named Investment for Jobs and Growth (IJG) with an allocation of EUR 369 billion. Amongst other funds included under the IJG goal, the European Regional Development Fund (ERDF) aims to strengthen economic, social and territorial cohesion in the European Union by correcting imbalances between its regions. In 2021-2027[212], it will enable investments in a smarter, greener, more connected and more social Europe that is closer to its citizens.

- **Connecting Europe Facility (CEF) Digital**[213]: The CEF supports the development of trans-European networks and infrastructures in the sectors of transport, telecommunications and energy. Under the Multiannual Financial Framework, the MMF,

[209] Recovery and Resilience Facility | European Commission (europa.eu)
[210] Additional funding of €78bn provided by the 20 National Broadband Plans (NBPs)
Source: Deloitte 2021
[211] 2021-2027 - EU allocations available for programming | Data | European Structural and Investment Funds (europa.eu)
[212] European Regional Development Fund - Regional Policy - European Commission (europa.eu)
[213] Connecting Europe Facility | Shaping Europe’s digital future (europa.eu)

the digital strand of CEF is worth €2.07 billion (in current prices) and will fund connectivity projects in the period 2021-2027. Action foreseen under the programme include:

- Developing and making available very high-capacity networks, including 5G systems, across Europe: in particular CEF will fund projects that contribute to deploying 5G infrastructures along major transport paths. In addition, projects that deploy 5G connectivity to smart communities, e.g. schools, hospitals and community centres to improve access to online services and digital skill will also be in scope of CEF funding.[214]
- Supporting increased security, resilience and capacity of the digital backbone networks in the EU
- Boosting the digitalisation of transport and energy networks

- **ESA Space for 5G and 6G Strategic Programme**[215]: In 2019, following the successful endorsement of the 5G Programme, ESA has established the “Space for 5G and 6G” Strategic Programme to better serve the space sector in the 5G/6G journey and opportunity it creates. The Space for 5G & 6G programme is focused on promoting, developing and validating converged hybrid networks to support the digitalization of industry and society, in a world where satellite is fully integrated in the connectivity networks. The main objectives of the programme related to 5G are the following:

  - Achieve full integration of satellite with terrestrial 5G networks
  - Engage verticals in 5G integrated (satellite and terrestrial) pilots
  - Drive standardisation activities to ensure full inclusion of satellite in 5G standards

  There are several funding opportunities and calls available in support of the Space for 5G and 6G programme.

- **The European Smart Networks and Services joint Undertaking (SNS JU)**[216]: The European Commission adopted its legislative proposal for a strategic European partnership on Smart Network and Services as a Joint Undertaking in February 2021. The SNS JU is jointly funded by Industry and the EU. The budget of the SNS JU is at least €1.8 billion for the period 2021-27. An EU contribution of €900 million will be at least matched by participating industry. The SNS JU provides financial support in the form of R&I grants to participants following open and competitive calls. The Joint Undertaking will coordinate research activities on 6G technology under Horizon Europe as well as 5G deployment initiatives under the Connecting Europe Facility Digital and other programmes.

[214] Source: https://digital-strategy.ec.europa.eu/en/activities/connecting-europe-facility
[215] Space for 5G | ESA TIA
[216] Smart Networks and Services Joint Undertaking | Shaping Europe’s digital future (europa.eu)

- **Horizon Europe**[217] (2021–2027): The Horizon Europe is the EU’s key funding programme for research and innovation with a budget of €95.5 billion. It aims at tackling the climate change, helping to achieve the United Nations Sustainable Developments Goals and to boost the EU’s competitiveness and growth.

- **InvestEU**[218] (2021–2027): The InvestEU Programme builds on the success of the Juncker Plan (European Fund for Strategic Investments - EFSI) for Europe, ended in December 2020, to mobilise both public and private investments to bolster innovation and access to finance in the European Union. For the next long-term EU budget 2021-2027, in June 2018 the Commission proposed to create this programme to bring EU budget financing in the form of loans and guarantees under one roof. The InvestEU Programme consists of 3 building blocks: the InvestEU Fund, the InvestEU Advisory Hub, and the InvestEU Portal. The InvestEU Fund[219] is expected to mobilise more than €372 billion of public and private investment through an EU budget guarantee of €26.2 billion that backs the investment of financial partners such as the European Investment Bank (EIB) Group and others. The InvestEU Fund combines 13 centrally managed EU financial instruments and the European Fund for Strategic Investments into 1 instrument.

  The InvestEU Fund is focused on the following 4 policy priorities:

  - Sustainable infrastructure
  - Research, innovation and digitalisation
  - Small and medium-sized companies
  - Social investment and skills

[217] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
[218] InvestEU | InvestEU (europa.eu)
[219] InvestEU Fund | InvestEU (europa.eu)

2.3.1.1 Selection of EU27 initiatives

The below table provides a sample of projects and initiatives ranging from testbeds to funding of collaborative projects to support the 5G ecosystem at country level:

Table 10: Selection of EU-27 relevant R&I initiatives

Country	Initiative/project	Short description
Austria	Gigabit Triple A[220]	"Gigabit Triple A: Awareness.Applications.Austria" is a EUR 10 million service and funding package of the Federal Ministry of Agriculture, Regions and Tourism and FFG to strengthen innovations around 5G applications and to support the digital progress of Austrian regions.
Denmark	Genius project[221]	Denmark’s Innovation Fund is supporting the launch of the Grand Solutions project GENIUS which aims to develop a 5G network for the low airspace. The project has a budget of DKK 24 million, of which DKK 14 million has been allocated from Innovation Fund Denmark. The aim of GENIUS is to develop a novel 5G Unmanned aircraft systems (UAS) network, building upon and shaping the current 5G roll-out, but optimized for 3D coverage of the lower airspace and providing the required safety and reliability for a U-space where drones can fly safely side by side with manned aviation beyond visual line of sight (BVLOS) of the pilot.
Estonia	Digital Testbed framework[222]	The Digital Testbed Framework is a form of collaboration between the Government of Estonia and interested stakeholders to cooperate in IT development without the complex web of procurement rules. This project enables anyone to build solutions for the digital state as well as get a proof of concept for their own commercial solutions.

[220] Gigabit Triple A: Awareness.Applications.Austria | FFG
[221] https://genius.aero
[222] Digital Testbed Framework - e-Estonia

Country	Initiative/project	Short description
Finland	5GTNF[223]	The general goal of 5G Test Network Finland (5GTNF) is to fill the gap between laboratory-based 5G and beyond testing environments and commercial network deployments, offer trialling support and tailored infrastructure configurations for telecom and vertical industries and scientific community and strengthen Finnish ecosystem position in beyond 5G R&D and utilization of 5G and AI. 5GTNF is a joint effort from industry, academia and Finnish government. Several projects are taking place within this framework. 5GTNF’s objectives are the following: - Provide integrated multi-site 5G and beyond technology and services test network for telecom and vertical industries and R&D organisations - Develop technologies and innovations related to beyond 5G network and radio enablers, cyber security, utilisation of AI and business models - Develop technologies and solutions for vertical industries; Smart Industry, Smart Cities and Living, Smart Mobility and Smart health and Wellbeing
Finland	5G-FORCE[224]	5G Test Network Finland (5GTNF) consortium offers an integrated technological environment for research and trials. The aim of the 5G-FORCE project is to study and develop 5G technology and the related 5G test network environment for the needs of research and development projects of various verticals.
Finland	Priority[225]	Priority will research, develop, and trial Critical Communication solutions for authorities and remote businesses. A key target will be to complement existing Mission Critical voice and messaging services with broadband data capability, using commercial 4G and 5G wireless networks. The project will focus on three application scenarios: 1) Search and capture 2) Smart rural business 3)

[223] Home - 5GTNF
[224] 5g-force
[225] PRIORITY - 5GTNF

Country	Initiative/project	Short description
		Emergency response. The solutions will be trialled in live network deployments, by applying the 5G-Force platform and scenario-specific technology blocks.
Finland	DEDICAT6G[226]	The DEDICAT6G project develops sixth generation (6G) wireless networks, which will be deployed in the early 2030s. The main aims are to achieve dynamic coverage extension and distributed intelligence for human-centric applications. The aims also include a more efficient use of resources; the reduction of latency, response time and energy consumption; the reduction of operational and capital expenditures, and the reinforcement of security, privacy and trust. The project involves four use cases to be demonstrated: smart warehousing, an enhanced user experience, public safety and a smart highway.
Finland	Sat5G[227]	Sat5G project will bring satellite communications into 5G by defining optimal satellite-based backhaul and traffic offloading solutions.
Finland	5G-RANGE[228]	The goal of the 5G-RANGE project is to design, develop, implement and validate the mechanisms to enable the 5G network to provide an economically effective solution for Internet access for remote areas.
France	Funding framework “Development of Digital Technologies”[229]	The Franco-German initiative, “Programme d’investissements d’avenir”, aims to support collaborative projects involving French and German players in order to ensure the development of

[226] Dedicat6G – Dynamic coverage Extension and Distributed Intelligence for human Centric Applications
[227] SaT5G Project - Sat 5G (sat5g-project.eu)
[228] Remote area Access Network for the 5th GEneration – Remote area Access Network for the 5th GEneration (5g-range.eu)
[229] Digital Technologies - 5G Networks (digitale-technologien.de)

Country	Initiative/project	Short description
		sovereign solutions for private 5G networks. It aims in particular to support French and German SMEs offering innovative solutions on telecom networks.[230]
France	Acceleration strategy on 5G and future telecommunications network technologies[231]	The strategy aims to establish a dialogue between equipment manufacturers, operators, industrialists, start-ups and investors in order to understand the possible obstacles to the appropriation of 5G by these actors, and to identify concrete actions that can be implemented to support French companies in the emergence of innovative 5G services. It is funded by: - €480 million in public funding to support priority projects by 2022 - up to €735 million in public funding by 2025. The final goal is to mobilize up to €1.7 billion in investments by 2025.

[230] https://www.bpifrance.fr/nos-appels-a-projets-concours/appel-a-projets-entre-la-france-et-lallemagne-pour-des-projets-dinnovation-en-matiere-de-reseaux-prives-5g-developpements-techniques-et-decosystemes

[231] Investissements d’avenir I Lancement de la stratégie nationale d’accélération sur la 5G et les futures technologies de réseaux de télécommunications | Gouvernement.fr

Country	Initiative/project	Short description
Germany	Funding framework “Development of Digital Technologies”[232]	The Federal Ministry for Economic Affairs and Energy (BMWi), together with the French Ministère de l'Economie et des Finances et de la Relance (MEFR), plans to fund bilateral innovation projects on the topic of "Technical developments and application ecosystems for private 5G networks". The funding is targeted at: - A “Main project” to build an ecosystem for private 5G networks based on open or virtualised components - Up to six “demonstration projects” to test the technologies in concrete application areas and to test them in practice. The application scenarios range from the areas of Industry 4.0, logistics, healthcare and to other economically or socially relevant application areas.
Hungary	Public initiative to support 5G uptake[233]	Hungary is launching a HUF5 billion initiative to help consumers switch from 3G devices to 4G/5G smartphones. Hungary’s National Media & Infocommunications Authority stated that from February 2022 a subsidy totalling HUF20.000 will be made available to help users upgrade to newer devices. This sum would fully cover the cost of around 250,000 device upgrades.

[232] Digital Technologies - 5G Networks (digitale-technologien.de)
[233] Hungary to subsidise 4G/5G device upgrades to facilitate 3G shutdown - Developing Telecoms

Country	Initiative/project	Short description
Italy	“Italia 5G” Plan[234]	The "Italia 5G" Plan is set up in a complementary and synergistic perspective with respect to the development path already started for national 5G networks and to the coverage obligations of mobile operators, in order to guide better public initiatives aimed at the creation of networks providing innovative and high-quality mobile services performance (e.g. transmission speed of at least 150 Mbit / s in download and at least 50 Mbit / s in Upload). With an allocation of € 2.02 billion, the plan aims to incentivize the deployment of 5G mobile networks in areas of market failure, in order to fully meet the needs of mobile connectivity capable of enabling the multiple use cases provided by the ITU, relating to the three categories enhanced Mobile BroadBand (eMBB), massive Machine Type Communication (m-MTC), Ultra-Reliable Low Latency Communication (URLLC)
Luxembourg	5G-EMIT[235]	5G-EMIT aims to propose and validate a data-driven network planning solution to recommend optimal network deployment strategies, while considering RF-EMF limits and the various features provided by new 5G technologies. This decision support system will aim at facilitating the deployment, compliance and sustainability of 5G in Luxembourg. 5G-EMIT will not only provide significant advances on the current state-of-the-art of network planning, design and optimisation but will also develop innovative assessment methodologies considering the new technological features related to 5G’s advanced antenna systems. As a support decision-making tool, the online software monitoring platform will provide a planer to predict the effect of specific deployment scenarios, as well as exposure predictions and estimates, all of which will be scientifically validated during the project. This national project will therefore be of high interest for operators eager to optimise the deployment of 5G infrastructures while meeting current regulations.

[234] Strategia BUL.docx (mise.gov.it)
[235] 5G-EMIT | Luxembourg Institute of Science and Technology (list.lu)

Country	Initiative/project	Short description
Luxembourg	Call for projects[236]	In the frame of the national 5G strategy and of the conference «Connecting tomorrow - 5G, broadband and beyond» (organised in Luxembourg in October 2021), the Department of Media, Telecommunications and Digital Policy launched a call for projects covering three categories: 5G showcase; science communication; innovative conference coverage.
Luxembourg	5G-INSIGHT[237]	5G-INSIGHT aims at providing advanced security mechanisms to detect and mitigate slicing attacks for 5G and beyond vehicular networks with special focus on the France-Luxembourg cross-border area. Through this INTER project co-funded by the Agence Nationale de la Recherche (ANR - FR) and the Fonds National de la Recherche (FNR - LU), researchers will make use of advanced Machine Learning algorithms to propose new techniques for detecting as well as predicting attacks and anomalies within 5G vehicular slices. 5G-INSIGHT will not only contribute to the current state of the art on cross-border 5G vehicular networks and network slicing, but also to the creation of synergies with other national, European, and cross-border 5G projects. The platform to be created internally will also be linked as much as possible with other ongoing 5G initiatives, to create a seamless picture on network planning solutions, considering the security and privacy aspects. Finally, the development of a proof of concept will demonstrate the ability of 5G-INSIGHT solutions to alleviate security threats, network vulnerabilities and attack risks in a virtualised cross-border environment.

[236] 5G - government.lu (gouvernement.lu)
[237] https://www.list.lu/en/informatics/project/5g-insight/

Country	Initiative/project	Short description
Luxembourg	5G-PLANET[238]	5G-PLANET will build on LIST’s expertise to propose a decision support system to plan and design 5G networks for cooperative, connected and automated (CCAM) mobility applications. This system will be the subject of demonstrations to raise public awareness about the interest of these technologies. To do so, LIST will rely on a Digital Twin approach, by creating a digital replica of Luxembourg’s 5G infrastructure. The objective is first and foremost to offer a visual and attractive showcase to raise the public awareness about: system architecture; connected mobility sector; decision support for Luxembourg. 5G-PLANET primarily intends to share LIST's experience on the planning and design of new 5G networks, by taking Luxembourg as a practical example, specifically targeting connected mobility applications and intelligent transport systems, which are among the most promising uses of 5G on a socio-economic level, although still requiring a few years before advanced implementation. The objective is to propose an awareness-raising platform that makes complex 5G-mobility concepts accessible to the greatest number of people in the long run.

[238] https://www.list.lu/en/informatics/project/5g-planet/

Country	Initiative/project	Short description
Netherlands	5Groningen[239]	Economic Board Groningen initiated the 5Groningen programme to investigate how 5G can accelerate and create new innovation. The 11 partners of 5Groningen have recently signed an agreement to keep the 5Groningen programme going also in the next two years. Cooperation with the European Space Agency (ESA) will also continue. The Northern Netherlands Partnership (SNN) awarded a contribution of more than €700,000 from the European Regional Development Fund (ERDF) to the 5G living lab. Economic Board Groningen and National Programme Groningen each will contribute €500.000 for the continuation of the 5Groningen programme in 2021-2022. The National Programme Groningen also makes €700.000 subsidy money available for SME entrepreneurs in the province of Groningen who are testing innovations with 5G in the 5G living lab.
Sweden	Arctic 5G Test Network[240]	The Arctic 5G Test Network aims to link the 5G test networks in Oulu, Finland, and Luleå, Sweden, by connecting them and engaging in active collaboration, creating an Arctic node within 5G through collaboration between universities, large ICT companies and SMEs. This enables cross-border testing and increases overall testing capabilities in the 5G networks.

[239] 5Groningen gaat nog zeker twee jaar door › 5Groningen
[240] Home | Arctic 5G Test Network

3 Strategic implications of the monitoring results

The table below outlines major strategic implications referring to the overall performance of EU27 against relevant targets, which will be updated on a quarterly basis (i.e. during each of the upcoming publications). 5G-related targets to be monitored throughout the publications have been sourced from EU Policy programmes including 5G AP; Digital Decade and Cybersecurity Toolbox This monitoring exercise will represent the basis for a full strategic discussion including roadmap to be included in the final report:

Targets: 5G AP; Digital Decade; Cybersecurity Toolbox	Performance/status	Bottlenecks identified	Solution/recommendation
Commercial launch of 5G services at least in one major city in all EU countries	Since January 2022, commercial 5G is now available in all 27 EU Member States.[241] All deployments to date cover major cities and urban areas.	None	-
Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways.	Based on data collected by the Commission in 2020, the baseline for population coverage in the EU is estimated at 14%.[242]	As a result of research performed at Member State level, the study team identified a lack of consistent reporting at MS level (for example coverage of major roads and railways is only reported in Finland).	A part of the solution is already contained in The Policy Programme “Path to the Digital Decade” which foresees a monitoring mechanism for the attainment of the 2030 targets based on key performance indicators, defined by the Commission in the DESI on a yearly basis.[243, 244]. This edition of the 5G Observatory report also includes a modelling exercise to estimate geographic (populated areas) and transport path coverage.
“Digital technologies including 5G…at the core of new products, new manufacturing processes and new business models”	The roll out of private 5G networks is still in a relatively early growth phase but will be an important contributor to the continued productivity of Member States and adoption of new technologies for enterprises that will support the ongoing development of the 5G ecosystem. 5G verticals appear to	A potential bottleneck could be the inconsistency in which bands will be used (affecting the prevalence of vertical rollouts) across member states.	Related to the potential bottleneck highlighted, a recommendation regarding the optimal bands identified for sharing and therefore used for local/private networks (for industrial applications) could harmonise deployment.

[241] Final launch in Lithuania announced in January 2020 by Telia
[242] Percentage of populated areas (i.e. percentage of all places where households are located, including remote areas) with coverage by 5G - measured as the total coverage of telecom operators in each country.
Source: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021DC0118
[243] Source: Proposal for a Decision establishing the 2030 Policy Programme “Path to the Digital Decade”
[244] For more information regarding 5G targets in the digital decade see: https://digital-strategy.ec.europa.eu/en/policies/5g-digital-decade

	be particularly developed in ports, whereas in other industries they are at an earlier stage. Most trials appear to be occurring within private networks although there are some examples of verticals which will run on public networks.		
Authorising 5G spectrum bands	The 3.6 GHz band has been most widely assigned. Twenty one out of 27 Member States have assigned this band. The second most popular band is the 700 MHz band, which has been assigned in nineteen out of 27 Member States. The least popular band is the 26 GHz band, which has only been assigned in seven Member States. Finally, five Member States have failed to assign any of the pioneer bands. A growing trend across Member States is making portions of the C-Band available to private enterprises, such as the dedicated 100 MHz portion available to verticals in Germany or countries such as Sweden and the Netherlands enabling sharing of spectrum to support local network deployments.	Lack of demand for the 26Ghz band. Further development of harmonised approach to spectrum sharing for local networks	Referring specifically to the 26GHz band, there have been differences in the way the band has been made available suggesting there is no “universal formula”. Most approaches however take into account the use of the band for industrial applications and 5G verticals.[245]

[245] From a technical perspective this is very much a band used to serve congestion in high capacity density networks as well which implies the need for a balanced approach.

Promoting pan-European multi-stakeholder trials[246]/ Developing Pan-European deployment of 5G corridors	Twelve "digital cross-border corridors" have been established to accommodate live tests of 5G for Cooperative Connected and Automated Mobility. In addition, at least eight Member States refer to the European deployment of 5G corridors along TEN-T networks in the interest of Single Market and cohesion in their recovery plans.[247]	17 of 27 Member States are involved in the existing 12 cross-border corridors.	Upcoming projects (including the support of CEF framework) and commitments of Member States in their recovery plans are expected to bridge existing gaps.
5G toolbox implementation	A large number of Member States have already taken concrete steps to implement the various strategic measures.	Based on the latest NIS report (2020), there are visible differences in terms of implementation maturity for different types of individual measures.[248]	The analysis presented in the report by NIS provides specific recommendations (next steps) based on identified findings for each of the Toolbox measures, highlighting areas requiring special attention in the next phases of the Toolbox implementation and monitoring (both at EU and MS level).

[246] The original 5G AP target Source: https://digital-strategy.ec.europa.eu/en/policies/5g-action-plan can be linked to the Digital Decade reference to Multi-Country Projects (MCPs): large scale projects facilitating the achievement of the targets for digital transformation of the Union and industrial recovery.
[247] CZ, ES, IT, LV, EL, LT plans.
Source: Commission Staff Working Document
[248] https://digital-strategy.ec.europa.eu/en/library/report-member-states-progress-implementing-eu-toolbox-5g-cybersecurity

4 Explorations and reflections

4.1 Initial reflection on tracking 5G geographic coverage

4.1.1 Build out needed to achieve policy goals

To measure progress towards the Digital Decade policy goal of uninterrupted 5G for all urban areas and transport paths by 2025 and all populated areas covered by 2030 it is helpful to have an indication of the build out required. This section deals with approximating the infrastructure needed for geographic rather than transportation coverage and focusses on the 2025 target. The next section (4.2) deals with coverage of transport paths.

For example, if country X now has 150 5G base stations, how close is it to achieving the 2025 goal? At its simplest, that depends on the size of the country and the distribution of its population. For a very densely populated country like Malta, covering 320 km^2, 150 base stations would probably be adequate, but for a large country like Germany (over 350,000 km^2) tens of thousands would be required.

Achieving the full potential of 5G also depends on delivering speeds significantly higher than 4G, along with the enhanced functionality to support verticals. We refer to this as “step change” 5G. This is only possible in higher frequency bands like 3.4-3.8 GHz and 26 GHz, not at the sub-1 GHz bands like 700 MHz. So to carry out a deeper analysis which takes into account 5G’s full possibilities, it is helpful to have approximate estimations of how many base stations would be required for “optimal” 5G.

This ties in with the Digital Decade target of all populated areas to be covered by 5G by 2030. Several studies[249] have concluded that covering whole countries with services at 3.4-3.8 GHz is uneconomic[250] as it requires the provision of too many base stations, many of them in areas which are almost uninhabited.

A more realistic target is 5G at 3.4-3.8 GHz in urban areas (with some use of 26 GHz) and the rest of the country being covered by sub-1 GHz bands. This is the model used in the estimates below.

4.1.1.1 Will some Member States find the goals more challenging?

In assessing progress towards the 5G Digital Decade goals it is also helpful to compare the difficulties faced by the different Member States. In simple terms it is much easier to provide 5G

[249] Oughton and Zoraida 2016 *Exploring the cost, coverage and rollout implications of 5G in Britain* https://www.nic.org.uk/wp-content/uploads/Exploring-the-Cost-Coverage-and-Rollout-Implications-of-5G-in-Britain-Oughton-and-Frias-report-for-the-NIC.pdf, William Webb (2016) *The 5G Myth* p54, PolicyTracker (2017) Infrastructure issues in 5G

[250] Except in small and densely populated countries, like Malta or Hong Kong

coverage in smaller countries like Malta, particularly if the country is densely populated. This offers a larger number of subscribers per base station, making the build out more cost effective.

The greatest challenge is faced by those countries with large land masses and large rural populations, where the number of subscribers per base stations is much lower. This issue is highlighted in the data on rural populations below.

4.1.1.2 Methodology & Data

In this section we propose a methodology which could be used to give an approximation of the number of base stations needed to provide 5G in 3.4-3.8 GHz and above in urban areas in a particular Member State.

The dataset we propose using comes from the Gridded Population of the World produced by Columbia University. This tells us the population densities in all countries, including the EU 27 and the landmass occupied by each density categorisation. We have categorised population densities of more than 250 people per km2 as urban areas and densities of above 1,000 people per km2 as cities. Densities of below 250 are categorised as rural areas.

It has been assumed that coverage in urban areas would primarily use micro and pico cells rather than macro cells, due to the necessity to provide significant capacity, the difficulties of finding macro cell sites in urban areas, and the coverage limitations associated with the topography and morphography of cities.

A 3.4-3.8 GHz micro/pico-cell has a typical cell radius of 1 km, producing area coverage of approximately 2.6 km^2. To calculate the number of base stations required we have divided the land area which is categorised as urban by 2.6 km^2. This does not take topography or morphography into account[251] and is intended as a useful and transparent approximation to aid comparison between countries of different sizes and populations.

To continue with the example of Malta, it is a country of 300 km^2, almost all of which (290 km^2) is urban i.e. having a population density of more than 250 people per km^2. Dividing 290 km^2 by 2.6 km^2 gives a figure of 111.5, which we round up to 120 to reflect the likely level of accuracy.

Doing the same calculations with Germany, the most populous Member State produces starkly contrasting figures because of its size and dispersed population. Its total area is 354,600 km^2, of with 74,500 km^2 categorised as urban, giving a requirement of 28,700[252] 5G base stations to cover this area.

[251] We note that impact of topography and morphograpy can have a significant impact on the number of required base stations but requires detailed radio coverage analysis in order to do so, which is not the intention of this analysis
[252] Rounded figure

We regard these figures not as the exact number of base stations needed but it generates as a minimum threshold for the number of base stations required for a feasible “optimal” 5G network in urban areas. The actual number needed is likely to be higher as the impact of buildings in urban areas reduces base station coverage and it is not always possible to find a site at optimal site to ensure maximum coverage. The most accurate estimation would require a detailed network planning exercise which is out of the scope of this report..

The advantage of our proposed approach is that it is uses objective, rigorous and transparent data which can be adjusted for other assumptions. However, we recognise that regulators and industry may have other approaches and we would welcome further debate in this area.

4.1.1.3 Build out requirements to fulfil 5G’s potential

The table below shows the approximate minimum number of base stations needed to provide a feasible 5G network at 3.4-3.8 GHz in urban areas using the methodology described above. These are figures for a single network, which could be shared between several operators. The table is ordered by the final column, which shows the countries which have the highest “optimal” 5G feasibility threshold.

Table 11: Number of base stations needed for “optimal” 5G in urban areas

Country	Total area in km^2	Urban areas as % of land mass	Size of urban areas in km^2	Number of people living in urban areas	% pop living in urban areas	“Optimal” 5G feasibility threshold (no of 3.5 GHz cells needed)
Germany	354,600	21%	74,500	42,766,000	53%	28,700
France	554,000	8%	44,300	39,933,000	62%	17,100
Spain	505,800	7%	35,400	32,275,000	70%	13,700
Italy	300,800	11%	33,100	50,829,000	85%	12,800
Poland	311,700	7%	21,800	20,465,000	53%	8,400
Netherlands	36,100	47%	17,000	14,014,000	84%	6,600
Belgium	30,700	46%	14,100	9,323,000	83%	5,500
Romania	237,200	5%	11,900	9,364,000	48%	4,600
Czech Republic	78,900	11%	8,700	6,358,000	60%	3,340
Portugal	92,600	8%	7,400	8,613,000	82%	2,850
Hungary	92,500	8%	7,400	4,831,000	50%	2,850
Greece	132,200	4%	5,300	7,122,000	65%	2,040
Slovakia	49,000	9%	4,400	2,537,000	47%	1,700

Country	Total area in km²	Urban areas as % of land mass	Size of urban areas in km²	Number of people living in urban areas	% pop living in urban areas	“Optimal” 5G feasibility threshold (no of 3.5 GHz cells needed)
Sweden	425,000	1%	4,300	5,086,000	52%	1,640
Austria	83,800	5%	4,200	4,531,000	53%	1,620
Denmark	43,100	9%	3,900	3,503,000	63%	1,500
Finland	322,300	1%	3,200	1,703,000	32%	1,240
Croatia	56,300	4%	2,300	1,785,000	43%	870
Bulgaria	111,200	2%	2,200	2,490,000	35%	860
Ireland	69,600	3%	2,100	3,003,000	62%	810
Slovenia	20,600	8%	1,600	1,191,000	56%	640
Estonia	43,300	3%	1,300	935,000	72%	500
Cyprus	8,900	9%	800	666,000	57%	310
Lithuania	64,800	1%	650	1,189,000	41%	250
Latvia	64,200	1%	640	1,005,000	51%	250
Luxembourg	2,600	19%	500	359,000	64%	200
Malta	300	92%	290	410,000	98%	120

We now consider how the above data can help guide policy-making.

4.1.1.4 Which Member States need the most base stations to achieve “optimal” 5G?

Looking at the Member States in the top third of the table these are predominantly larger countries in terms of surface area, particularly where the urban population is dispersed rather than concentrated in a few areas. This applies to Germany, France, Spain, Italy, Poland and Romania.

Two relatively small countries also appear in the top third: the Netherlands and Belgium. This is because nearly half of their land mass is categorised as urban. This increases the area that needs to be covered by the 5G base stations.

Conversely, Sweden, Greece and Finland need far fewer “optimal” 5G base stations, despite being relatively large countries, because their urban populations are concentrated in small areas: just 1% of the landmass for Sweden and Finland and 4% for Greece.

4.1.1.5 Which Member States face the largest economic challenge in delivering “optimal” 5G?

The more subscribers can use a base station, the easier it is to repay its cost of deployment and this aspect of the 5G economic challenge can also be examined using the collected data.

The table below approximates how many people each base station in a “optimal” 5G network can potentially reach. This is done by dividing the total urban population by the number of base stations which constitute the national feasibility threshold. e.g. in Germany the 5G feasibility threshold is 28,700 base stations and these could potentially reach the 42.7 million people (53% of the population) who live in urban areas. Dividing 42.7 million by 28,700 this gives a rounded figure of approximately 1,500 people per base station. In Malta, a much smaller and more densely populated country, each bases station could potentially reach 3,600 people.

The table below is sorted by the putting the smallest number of possible subscribers first, as this one indication of the revenues which the network can raise.

Table 12: Approximate number of subscribers per base station in 5G networks

Country	National feasibility threshold	Approximate population per base station in “optimal” 5G network
Finland	1,240	1,400
Germany	28,700	1,500
Slovakia	1,700	1,500
Belgium	5,500	1,700
Hungary	2,850	1,700
Czech Republic	3,340	1,900
Slovenia	640	1,900
Estonia	500	1,900
Luxembourg	200	1,900
Netherlands	6,600	2,100
Romania	4,600	2,100
Croatia	870	2,100
Cyprus	310	2,200
France	17,100	2,300
Denmark	1,500	2,300
Spain	13,700	2,400
Poland	8,400	2,400
Austria	1,620	2,800
Bulgaria	860	2,900
Portugal	2,850	3,000
Sweden	1,640	3,100
Greece	2,040	3,500
Malta	120	3,600
Ireland	810	3,700
Italy	12,800	4,000
Latvia	250	4,100

Country	National feasibility threshold	Approximate population per base station in “optimal” 5G network
Lithuania	250	4,800

This data shows that Member states with the following characteristics face the largest challenge:

- The largest countries (e.g. Finland, Germany, Spain, Romania)
- Countries with a dispersed urban population (e.g. Belgium)
- Countries with a small population (e.g. Slovakia, Hungary, Slovenia, Estonia, Luxembourg)

However, we should bear in mind that other factors also influence the monetary implications of building base stations, such as the relative wealth of the country and terrain-related issues.

4.1.1.6 Which countries have the danger of a 5G rural divide?

While we have argued that it is only economic to extend C-band 5G to urban areas, in some countries this will exclude a large section of the population. In those countries with large rural populations there is a danger that lack of 5G will compound already identified inequalities in poverty, social exclusion and digital skills.

The population density data can also highlight those countries with large rural populations, as shown in the table below.

Table 13: Size of rural populations in Member States

Country	% population living in rural areas	Number of people living in rural areas (M)	Total pop (M)
Finland	68%	3.62	5.32
Bulgaria	65%	4.62	7.12
Lithuania	59%	1.71	2.90
Croatia	57%	2.37	4.15
Slovakia	53%	2.86	5.40
Romania	52%	10.14	19.51
Hungary	50%	4.83	9.66
Latvia	49%	0.97	1.97
Sweden	48%	4.69	9.78
Austria	47%	4.02	8.55
Germany	47%	37.92	80.69
Poland	47%	18.15	38.61
Slovenia	44%	0.94	2.13
Cyprus	43%	0.50	1.17

Country	% population living in rural areas	Number of people living in rural areas (M)	Total pop (M)
Czech Republic	40%	4.24	10.60
France	38%	24.48	64.41
Ireland	38%	1.84	4.84
Denmark	37%	2.06	5.56
Luxembourg	36%	0.20	0.56
Greece	35%	3.84	10.96
Spain	30%	13.83	46.11
Estonia	28%	0.36	1.30
Portugal	18%	1.89	10.50
Belgium	17%	1.91	11.23
Netherlands	16%	2.67	16.68
Italy	15%	8.97	59.80
Malta	2%	0.01	0.42

This data underlines that if a Member States’ rural population is very large, the absolute numbers of people missing on the full benefits of 5G is a potential concern. This is particularly noticeable in some of the poorer Member States. e.g. Bulgaria, Lithuania, Croatia, Slovakia, Romania and Hungary: all have half or more of their population living in rural areas. Latvia is just behind at 49% rural.

The most striking example is Romania, where over 10 million people would miss out if “optimal” 5G were only available in urban areas.

4.1.2 Conclusions

In this section we have argued that population density figures when used in conjunction with base station coverage estimates can provide a transparent, objective and replicable way of giving an approximation of the minimum number of base stations feasibly required to provide “optimal” 5G in each Member State. We do not claim to have provided the exact number needed - that would require comprehensive network planning - rather this is a useful estimate for comparative purposes.

This methodology suggests that the Member States with the largest landmass, and those with the most dispersed urban population will face the greatest challenge in deploying “optimal” 5G because of the larger number of base stations required and the small number of potential subscribers for each installation. Counties with a large rural population are a particular concern because in absolute terms the number of people missing out could be very large if 5G is only deployed in urban areas.

4.2 Initial reflection on tracking 5G transport paths coverage

Delivering 5G coverage at 3.5 GHz along transport paths will be challenging, this is because access and deployment of infrastructure is needed close to or directly on the transport corridor itself. For example, in the case of achieving 100% 5G coverage along the railway, would require trackside access and deployment of infrastructure to ensure full coverage along cuttings and tunnels. Coverage of the railway in flat terrain is relatively straightforward from non-trackside infrastructure by the MNOs, but unlikely to achieve the 100% coverage required.

The same is true for major highways in Europe. In order to achieve 100% 5G coverage, the ideal situation is to deploy roadside infrastructure as there will be many areas where existing coverage from the MNOs is not sufficient to achieve the desired experience of 5G. In both cases, there is a good chance that fibre runs along both rail and highway routes in many countries, the challenge is accessing the fibre for the new infrastructure in the places where it is needed and ensuring there is sufficient capacity to support the traffic. In some cases, for regulatory and safety reasons, the existing fibre on these routes are reserved for the (rail or road) operational traffic with commercial traffic not permitted (i.e. this raises State Aid concerns). It is further noted, that the telecommunications infrastructure would need to be deployed at regular intervals along the routes, in the case of rail this would likely mean access to the electrification gantries, which in most countries is not deployed along the entirety of the route.

Nevertheless, assuming these barriers can be overcome in Member State countries, dedicated infrastructure will be needed to serve both trains (connecting to rooftop antennas rather than users inside the trains having to overcome relatively high attenuation of the train body) and cars (connecting to both passengers in the cars and to the car itself).

4.2.1 Methodology for estimating 5G coverage on major railway routes

In this approach an approximation of the number of base stations that would be needed for an example Member State’s major railway routes is provided.

Dedicated infrastructure for 5G using frequencies above 3.5 GHz may require extensive in-fills in addition to equipment deployed on existing masts on the trackside. In addition, where there is already electrification along the track, gantries can be used for mounting equipment [See study by Mott MacDonald]. This would ensure the required inter site distance can be achieved to ensure the cell edge service level can be met.

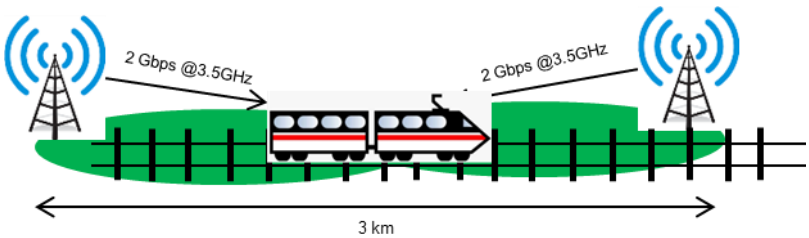
In this example, the railway routes in Germany have been chosen due to the extensive route length (33,331 km) but also since there is fibre available, electrification on parts of the route and work already underway to provide better mobile coverage along rail routes[253]. This means many of the regulatory and commercial barriers have been overcome.

[253] https://railway-news.com/db-and-deutsche-telekom-plan-seamless-mobile-network-along-germanys-railways/

Estimated number of trackside base stations for railways in Germany can be calculated as follows:

- Determine target 5G throughput to train = 2 Gbps per train in each sector. This is based on peak speeds expected for cell sites
- Total railway length for Germany = 33,331 km[254] assuming there is fibre available and gantries for electrification
- Calculate the minimum inter-site distance of trackside infrastructure at 3.5 GHz: Assumed cell radius = 1.5 km to achieve 2 Gbps per sector cell capacity, thus an inter-site distance = 3km (2 x 1.5km)
- Conservative total number of sites needed: 33,331/3 = 11,110 sites for all railway routes in Germany. Note Deutsche Bahn is investing hundreds of millions of Euros to boost mobile coverage on the railways for 800 new sites
- This is a rough approximation based on assumptions including:
    - Each site can deliver full coverage (ignoring bends)
    - No coverage from other MNO roadside infrastructure
    - No interference, clutter or other geographical considerations

There are around 3000 - 4000 existing GSM-R masts providing coverage along the rail routes in Germany. Therefore, these would need to be upgraded to support 3.5 GHz. This raises the issue of load bearing on existing sites, which means a survey of all masts in needed to check whether additional antennas can be mounted on the mast or not to ensure it does not exceed load bearing limits.



[254] https://en.wikipedia.org/wiki/Rail_transport_in_Germany

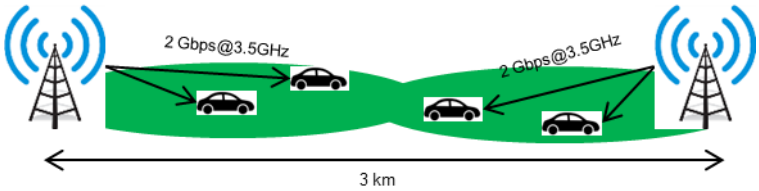
4.2.2 Methodology for estimating 5G coverage on major highways

In this approach an approximation of the number of base stations that would be needed for an example Member State’s motorway and major roads. It is similar to the approach used for rail and would require dedicated roadside infrastructure to achieve the 5G targets:

In this example the number of roadside base stations for motorways in France have been estimated. This is because the road length is quite extensive and will yield an outcome on the upper limits of the number of required base stations:

- Determine target throughput to vehicles. 50 Mbps per vehicle in each sector has been assumed on the basis that a relatively large number of vehicles could be within a cell depending on traffic conditions. In addition, 50 Mbps would enable all passengers of a four passenger vehicle, to do high quality video streaming simultaneously
- Total motorway lengths for France = 11,761 km[255][1]
- Calculate the minimum inter-site distance of roadside infrastructure at 3.5 GHz: Assumed cell radius = 1.5 km to achieve 2 Gbps per sector cell capacity, thus an inter-site distance = 3km (2 x 1.5km)
- Conservative total number of sites needed: 11,761/3 = 3920 sites for all motorway routes in France
- This is a rough estimation based on assumptions including:
    - Each site can deliver full coverage (ignoring bends)
    - No coverage from other MNO roadside infrastructure
    - Assumes max 40 vehicles per sector to achieve peak per vehicle throughput. This can be multiplied by the number of operators in the market so potentially 160 vehicles per sector or 320 vehicles between sites (over 3km stretch)

[255] https://www.statista.com/statistics/449660/france-timeline-of-total-motorway-length/



4.2.3 Conclusions of 100% 5G coverage of transport paths

The high level analysis has showed that in order to achieve 100% 5G coverage along railway routes and major roads, depends in countries where the length of railway track or major roads is large, many thousands of additional sites are needed. Deployment of the infrastructure and access to the roadside/trackside presents a number of practical, regulatory and commercial challenges that will need to be overcome. It would be useful for the 5G Observatory to capture a range of aspects for tracking transport path coverage including for each Member State:

- Progress in percentage of 5G coverage (for a given acceptable minimum service) for both road and rail corridors – identify and classify length of both major road and rail routes
- Number of base stations needed to achieve desired coverage along road and rail routes
- Identify barriers of access to trackside/roadside, fibre and deployment of infrastructure including description of solutions

4.3 Forecasting progress towards 2025

This chapter features a summary of existing projections for the forecasting towards 2025 5G-related targets and in some cases even later. The data presented in the table below has been compiled from different sources and reports produced by a range of analysts and industry stakeholders. The scope of the forecast models of the studies is focused on Europe, with some sources covering also the global level.

Reference/study	Year of publication	Scope	Summary outcome	Methodological framework/approach
Analysys Mason, Costs and benefits of 5G geographical coverage in Europe[256]	2021	Europe (EU27)	Scenario A: Enhanced mobile broadband (eMBB) roll-out by multiple Mobile Network Operators (MNOs) will total EUR 4-10 billion per network in the largest markets. Across Europe as a whole, the investment will be around EUR 150 billion. The modelling suggests that MNOs will deploy 3.5 GHz on a commercial basis to achieve **c.30-60% population coverage by 2026**. Scenario B: Extending 5G coverage to **near-universal geographical coverage using 700MHz** might result in an additional single network cost of EUR 4	Building on a previous study conducted in 2020, 5G investment in Europe and associated costs and benefits were modelled under three deployment scenarios and for 13 different use cases. The scenarios are as follows: • Scenario A: The cost and extent of commercially led 5G enhanced mobile broadband (eMBB) roll-out in different European markets (using a combination of new 5G pioneer plus legacy mobile bands), referred to as the 5G ‘base case’ • Scenario B: The additional investment needed to deliver near-universal geographical coverage using a low-frequency 5G layer (700MHz), referred to as the ‘low-frequency 5G case’ • Scenario C: The additional investment needed to extend 3.5GHz mid-band coverage beyond the base case to cover road, rail and rural use cases (including fixed wireless access into homes and businesses, and smart agriculture), referred to as the ‘full-5G mid-band coverage case’ The 13 use cases are as follows: urban high-capacity locations (‘urban hotspots’);

[256] Analysys Mason 2021

			billion (as a best-case estimate, featuring cooperation between industry and policy makers to achieve a roll-out structure minimising duplication of network) Scenario C: A total additional investment of EUR 20 billion across Europe needed to cover road, rail and agricultural areas (also providing coverage for fixed-wireless access [FWA] and construction use cases). This assumes that the same 3.5GHz 5G infrastructure can be shared by different use cases (while meeting the specific requirements of each use case) and that a single multi-use case network would be shared by operators outside of commercial areas. 26GHz deployment alongside 3.5GHz will be especially useful for 5G FWA use.	construction; broadband into homes and offices delivered via 5G fixed-wireless access (FWA); agriculture; road; rail; smart factories; mining; ports; airports; energy and utilities; healthcare and hospitals; municipal buildings.

GSMA, The Mobile Economy Europe 2021[257]	2021	Europe	In 2020, 472 million people in Europe (86% of the population) subscribed to mobile services. Eastern and Southern European Countries will the fastest growth rates of subscriptions by **2025 (reaching 480 million**), which will still be modest compared to those of Latin America or Sub-Saharan Africa. In European markets, the number of mobile internet users is expected to surge throughout the region, quadrupling overall by 2026. **By the end of 2025, Europe will feature 276 million 5G connections,** with the Nordic and Western Europe recording the highest adoption rates. In Europe, the 5G adoption (percentage of total connections) in 2025 is expected to be 40%. Operator investment to support 5G rollout will total EUR 145 billion by 2025.	Representing the interests of mobile operators worldwide, the GSMA is considered an industry reference point of global mobile operator data, analysis, and forecasts, publishing annually industry reports and research. GSMA’s annual state of mobile economy reports (global and regional versions) provide market intelligence (technology, socio-economic and financial datasets) through their in-house research team (i.e. proprietary models/forecasting methodology and datasets).

[257] GSMA, The Mobile Economy – Europe 2021

Northstream, 5G Outlook in Europe[258]	2019	4 EU Member states (Germany, France, Italy and Spain) + UK	In terms of population coverage for the projected 5G network rollout, **95% population coverage** was expected to be reached by EU countries analysed **by 2023/2024**. The same level of coverage was projected to be achieved 3 years earlier (2020/2021) in the US and Japan.	A theoretical 5G rollout on mid-band spectrum was modelled in terms of population coverage for the respectively largest operator across seven countries: US, Japan, Germany, France, Italy, UK and Spain. While US and Japan were expected to lead in deployment pace, the European countries were forecasted to be relatively slower. For the purpose of the study, the analysed European countries (with UK still part of the EU at the time of the analysis) were chosen as representative for Europe because they were the only ones that already assigned mid-band spectrum to MNOs when the study began.
Ericsson, Mobility Report[259]	2021	Global	5G is expected to be the fastest-deployed mobile communication technology in history and is forecast to cover about **75 % of the world’s population in 2027**. In addition, it is expected that 5G will account for nearly half of all mobile subscriptions by **2027 (4.4 billion, 49 %).** **Western Europe** is expected to reach 430 million of 5G subscriptions **by 2027, while Central and Eastern Europe** will reach 230 million in the same period.	The forecast models are established using historical data from various sources, validated with Ericsson internal data, including measurements in customers networks and industry analyst reports. Future developments are estimated on macroeconomic trends, user trends, market maturity and technological advances.
Dialogic[260]	2021	Netherlands	Between **296** and **726** new antenna sites	Demand for new antennas was modelled by comparing expected demand for mobile

[258] Northstream, 5G Outlook in Europe
[259] Ericsson, Mobility Report 2021
[260] Study for the Dutch Ministry of Economic Affairs and Climate

			need to be deployed **by 2026** to fulfil requirements set by Dutch regulator.	network capacity (distinguishing between 3 growth scenarios), with expected capacity offered by the current networks, and considering technological upgrades and deployment of new spectrum (e.g. 3.5 GHz and 26 GHz bands). This results in an accurate estimation of the number of base stations likely to encounter a capacity bottleneck between 2021 and 2026. For these base stations, further analysis was performed to determine how many new base stations would be required to provide the demanded capacity. The results are then translated to a number of antenna sites, in order to account for potential site sharing between the operators.
Commission Staff Working Document accompanying the 2030 Policy Programme “Path to the Digital Decade”[261]	2021	EU27	80% of population will be covered by 5G in 2025 with all populated areas covered by 2030.	The projected 5G coverage growth is based on an increase of the planned investments in 5G infrastructure (by an approximate factor of 25%) to fill in the estimate investment gap to reach the set deployment target by 2030. 5G coverage is projected using the historical evolution of 4G coverage (2011-2020) taking into account completed and planned spectrum assignments.

[261] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2021:0247:FIN:EN:PDF

5 Conclusions and main updates

This fourteenth quarterly report of the European 5G Observatory for the fourth quarter of 2021 provides an overview of recent 5G developments and trends at EU27 level and contextualises the main findings in light of international developments. The main updates in this publication include:

- **Supply market trends:** an additional section providing an overview of the major procurement announcements by mobile operators of which vendors have been selected for 5G roll outs

- **An exploratory chapter (“explorations and reflections”):** containing initial reflections on tracking progress of 5G coverage (geographic and along transport paths), as well as an exploration of the future towards 2025 targets based on existing research, as described below:

    - **Modelling 5G geographic and transport coverage:** an exercise approximating the infrastructure needed for geographic (populated areas) and transportation coverage at 3.4-3.8 GHz (“optimal 5G”), focusing on the 2025 uninterrupted 5G target for all urban areas and transport paths. When it comes to assessing progress towards the 5G Digital Decade goals, the coverage estimation reflects on the difficulties faced by Member States with larger land masses, bigger rural populations and less densely populated areas. Based on 2 selected examples, the transport paths coverage analysis highlights the challenges associated with deployments along extensive road and railways networks to achieve desired coverage.

    - **Forecasting progress towards 2025:** featuring a summary of existing projections for the forecasting towards 2025 5G-related targets produced by a range of analysts and industry stakeholders to anticipate EU 27 progress towards the achievement of EU Policy (5G AP and Digital Decade Targets).

- **3rd European 5G Observatory Stakeholder Workshop report:** the minutes of the workshop organised by the study team are appended to this report to provide the opportunity to review the main findings and to exchange views on the current status of 5G deployment and the latest market trends affecting 5G progress.

In addition to these new sections, the report continues the analysis on progress with commercial launches (including base station deployment and coverage figures), spectrum assignments, private network and trials launched.

ANNEX 1 Annexes

5.1 Detailed Results by country

5.1.1 Austria

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 1,400 locations(Sept 2021 overview based on Ookla).[262] Individual operator announcements: A1 telekom network at the end of January 2020 launched its commercial 5G services covering 350 locations across 129 municipalities. [263]Magenta Telekom ended 2020 with 1,200 5G sites nationwide[264]	
	- Number of base stations deployed (progress of deployments	1,252[265]	
	- Network performance: speed	200 Mbit/s[266]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	65.8%[267]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	50% (overall) 7.48% (rural)[268]	

[262] Drei lists 78 cities, while Magenta mentions 1,400 locations across the country
[263] https://www.rcrwireless.com/20210104/5g/magenta-telekom-5g-network-reaches-1200-sites-across-austria
[264]https://www.rcrwireless.com/20210216/carriers/austria-remains-a-5g-pioneer-even-as-infrastructure-fees-threaten-rollout
[265] Source: EC
[266]Source : RTR
[267]Source DESI
[268] Source : DESI (2020 data)

	- 5G corridors	Brenner Corridor IT-AT-DE	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	**Implemented**[269]	
	- 5G verticals (trials & initiatives)	None identified	
Other (indirectly relevant) targets[270]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	53%[271]	

5.1.2 Belgium

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 100 locations (Sept 2021 overview based on Ookla).	
	- Number of base stations deployed (progress of deployments	206[272]	
	- Network performance: speed	70 Mbps[273]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make	3.3%[274]	

RTR reports 55 per cent 5G population coverage in Q4 2020 Source: RTR

[269] Regional licences in 3400-3800 MHz

[270] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.

[271] €1.2 billion (improved digital connectivity; easing access to digital education; boosting future-oriented, transformative and innovative research)
Source: https://ec.europa.eu/info/system/files/austria-recovery-resilience-factsheet_en.pdf

[272] Source: EC

[273] Overall mobile data speed 08/21; Source : Ookla

[274] Source: DESI (5G readiness)

	these bands available for 5G		
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	4.43% 0% (rural)[275]	
	- 5G corridors	Antwerp-Rotterdam-North Sea (Vlissingen) BE-NL	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	**None**	
	- 5G verticals (trials &) initiatives	2 trials identified	
Other (indirectly relevant) targets[276]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	27%[277]	

5.1.3 Bulgaria

Target	Indicator(s)	Performance	On Track

[275] Source : DESI (2020 data)
[276] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[277] € 1.1 billion (reinforcing cyber resilience and security; education 2.0; e-services)
Source: https://ec.europa.eu/info/sites/default/files/belgium-recovery-resilience-factsheet_en.pdf

-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 190 locations (Sept 2021 overview based on Ookla).	
	- Number of base stations deployed (progress of deployments	257[278]	
	- Network performance: speed	226.6 Mbps[279]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[280]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% 0% (rural)[281]	
	- 5G corridors	"Thessaloniki, Sofia-Belgrade EL-BG-RS"[282]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	**None**	
	- 5G verticals (trials & initiatives)	1 trial identified	

[278] Source: EC
[279] 5G speeds 09/2021; Source : Ookla
[280] Source: DESI (5G readiness ; 2020 data)
[281] Source: DESI (2020 data)
[282] https://digital-strategy.ec.europa.eu/en/news/new-5g-cross-border-corridor-connected-and-automated-mobility-announced-digital-assembly-2018

Other (indirectly relevant) targets[283]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[284]	

5.1.4 Croatia

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	45 Croatian cities and a population of 1.7 million[285]	
	- Number of base stations deployed (progress of deployments	449[286]	
	- Network performance: speed	78 Mbps[287]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[288]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% 0% (rural)[289]	
	- 5G corridors	No agreement/project identified	

[283] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[284] Source: https://www.nextgeneration.bg/upload/36/Bulgaria_Recovery_and_Resilience_Plan_ENG.pdf
[285] Source : Hrvatksi Telecom
[286] Source: EC
[287] Overall mobile data speed 08/21; Source : Ookla
[288] Source: DESI (5G readiness)
[289] Source : DESI (2020 data); Hrvatski Telecom reports an outdoor population coverage of 34%

-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	**Proposed**[290]	
	- 5G verticals (trials & initiatives)	0 trials identified	
Other (indirectly relevant) targets[291]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	20%[292]	

5.1.5 Cyprus

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 10 locations (Sept 2021 overview based on Ookla).	
	- Number of base stations deployed (progress of deployments	423[293]	
	- Network performance: speed	136.18 Mbps[294]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	66.7%[295]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[290] Regional licences in 3410-3800 MHz
[291] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[292] € 497 million (digital transition of the public administration; digital connectivity of rural areas; digitalisation of higher education)
Source: https://ec.europa.eu/info/sites/default/files/com-2021-401-croatia_factsheet_en.pdf
[293] Source: EC
[294] Overall mobile data speed 08/21; Source : Ookla
[295]Source: DESI (5G readiness)

urban areas and major roads and railways. (by 2025)	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% 0% (rural)[296]	
	- 5G corridors	No agreement/project identified	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	**None**	
	- 5G verticals (trials &) initiatives	0 trials identified	
Other (indirectly relevant) targets[297]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	23%[298]	

5.1.6 Czechia

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in	- Urban areas covered (progress of deployments)	circa 550 locations (Sept 2021 overview based on Ookla).[299]	

[296] Source : DESI (2020 data); Cyta planned initial population coverage of 70%
[297] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[298] € 260 million (supporting connectivity; digitisation of public services; promoting digital educations and skills; enabling the digital health transition)
Source: https://ec.europa.eu/info/sites/default/files/com-2021-398-cyprus_factsheet_en.pdf#:~:text=LAYING%20THE%20FOUNDATIONS%20FOR%20RECOVERY%3A%20Cyprus%E2%80%99s%20recovery%20and,billion%20in%20grants%20and%20%E2%82%AC200%20million%20in%20loans.
[299] More than 130 cities and smaller municipalities covered by Vodafone and 60 cities by O2.

one major city in all EU countries (by 2020)	- Number of base stations deployed (progress of deployments	1,073[300]	
	- Network performance: speed	58.46 Mbps[301]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	66.7%[302]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% 0% (rural)[303]	
	- 5G corridors	Czech-Bavarian 5G corridor[304]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	**None**	
	- 5G verticals (trials & initiatives)	0 trials identified	

[300] Source: EC
[301] Overall mobile data speed 08/21; Source : Ookla
[302] Source: DESI (5G readiness)
[303] Source : DESI (2020 data); T-mobile reports population coverage of 10.4%, Vodafone over 20%
[304] https://www.mpo.cz/en/guidepost/for-the-media/press-releases/thanks-to-the-cooperation-between-the-czech-republic-and-bavaria--europe-will-be-better-digitally-interconnected---253192/

Other (indirectly relevant) targets[305]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[306]	

5.1.7 Denmark

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 16 locations (Sept 2021 overview based on Ookla).[307]	
	- Number of base stations deployed (progress of deployments	3,146[308]	
	- Network performance: speed	103.35Mbps [309]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	33.3%[310]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	80% 75% (rural)[311]	

[305] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[306]€ 1.7 billion (digital skills for the digital age; e-services; fostering the digital transition of the economy)
Source: https://ec.europa.eu/info/sites/default/files/com-2021-419-czechia_factsheet_en.pdf
[307] Initial launch by TDC covered larger urban areas such as Copenhagen, Aarhus and Odense, with planned nationwide (80%) population coverage by September 2020. .
[308] Source: EC
[309] Overall mobile data speed 08/21; Source : Ookla
[310]Source: DESI (5G readiness)
[311]Source : DESI (2020 data);

	- 5G corridors	Nordic Way2 NO-SE-FI-DK [312]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	**Proposed**[313]	
	- 5G verticals (trials & initiatives)	0 trials identified	
Other (indirectly relevant) targets[314]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	25%[315]	

5.1.8 Estonia

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 19 locations (Sept 2021 overview based on Ookla)[316]	
	- Number of base stations deployed (progress of deployments	Estimated 100 areas[317]	
	- Network performance: speed	70.44 Mbps[318]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make	0%[319]	

[312] https://www.nordicway.net/
[313] 3740–3800 MHz under investigation
[314] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[315] € 89 million (digital strategy; high-speed internet; SME's digital transition)
Source: https://ec.europa.eu/info/system/files/denmark-recovery-resilience-factsheet_en.pdf
[316] Telia reports coverage in 50 different locations and regions
[317] Based on Telia announcement in 2021
[318] Estonia's Mobile and Broadband Internet Speeds - Speedtest Global Index
[319] Source: DESI (5G readiness)

	these bands available for 5G		
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% 0% (rural)[320]	
	- 5G corridors	Tallin-Riga–Kaunas-Vilnius EE-LV-LT[321]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	3 trials identified	
Other (indirectly relevant) targets[322]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[323]	

5.1.9 Finland

Target	Indicator(s)	Performance	On Track

[320] Source : DESI (2020 data); Telia reports its 5G networks reaching most of the population and cities in October 2021
[321] Home - 5g routes project (5g-routes.eu)
[322] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[323] € 204 million (Digitalising companies; Digitalising public administration; Increasing connectivity).
Source: factsheet-estonia_en.pdf (europa.eu)

-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 290 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	3,000[324]	
	- Network performance: speed	204.8 Mbps[325]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	99.2%[326]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	In late 2020, 100 Mbps 5G networks covered 17% of Finland's main roads and highways and 18% of the railway network.[327]	
	- Population coverage	76% of Finnish households[328]	
	- 5G corridors	- Nordic Way2 NO-SE-FI-DK [329] - E8 "Aurora Borealis" NO-FI	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	Implemented[330]	
	- 5G verticals (trials & initiatives)	4 trials identified	

[324] Source: EC
[325] Benchmarking the Global 5G Experience — September 2021 | Opensignal
[326] Source: DESI (5G readiness)
[327] Fast 5G already available to more than 1.8 million Finnish households | Traficom
[328] Half of the internet usage by Finns travels through the mobile network, 5G networks are being built at a rapid pace in the most densely populated areas | Traficom
[329] https://www.nordicway.net/
[330] 24.25–25.1 GHz

Other (indirectly relevant) targets[331]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	27%[332]	

5.1.10 France

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 20,000 locations (Sept 2021 overview based on Ookla)[333]	
	- Number of base stations deployed (progress of deployments	22,636[334]	
	- Network performance: speed	72.47 Mbps[335]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	59.2%[336]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	41.75%[337]	
	- 5G corridors	Barcelona-Perpignan, Santander-Biarritz	

[331] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[332] € 301 (Digital connectivity; Rail services fit for future; Digital innovations for social welfare and health care services; Continuous learning; Recruiting international talent). Source: factsheet_finland_en.pdf (europa.eu)
[333] For instance Bouygues Telecom reports 5G coverage in 5 cities and over 2500 municipalities
[334] Observatoire5G_France_16122021.pdf (arcep.fr)
[335] France's Mobile and Broadband Internet Speeds - Speedtest Global Index
[336] Source: DESI (5G readiness)
[337] Iliad France population coverage. Source: iliad Group - Our presence in France

		ES-FR [338]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	Implemented[339]	
	- 5G verticals (trials & initiatives)	3 trials identified	
Other (indirectly relevant) targets[340]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[341]	

5.1.11 Germany

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 5,400 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	51,726[342]	
	- Network performance: speed	113.4 Mbps[343]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	100%[344]	

[338] 5GMED – Future mobility in the Mediterranean Cross Border Corridor
[339] 2575–2615 MHz
[340] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[341] € 1 billion (digitalisation of companies; digitalisation of schools; digitalisation of public administration). Source: france-recovery-resilience-factsheet_en.pdf (europa.eu)
[342] Source: EC
[343] Germany, August 2021, 5G Experience Report Report | Opensignal
[344] Source: DESI (5G readiness)

-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	80%[345]	
	- 5G corridors	- Brenner Corridor IT-AT-DE[346] - Metz-Merzig-Luxembourg FR-DE-LU[347] - CZ-Bavaria: Prague-Munich	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	Implemented[348]	
	- 5G verticals (trials & initiatives)	17 trials identified	
Other (indirectly relevant) targets[349]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	52%[350]	

5.1.12 Greece

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in	- Urban areas covered (progress of deployments)	circa 20 locations (Sept 2021 overview based on Ookla)	

[345] Deutsche Telekom to cover 90% of German population with 5G this year (rcrwireless.com)
[346] Home page - 5G CARMEN
[347] 5GCroCo
[348] 3700–3800 MHz & 26 GHz
[349] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[350] € 5.25 billion (investment in microelectronics and communication technologies; next generation cloud infrastructures and services; digitisation of public services) Source: germany-recovery-resilience-factsheet_en.pdf (europa.eu)

one major city in all EU countries (by 2020)	- Number of base stations deployed (progress of deployments	1,106[351]	
	- Network performance: speed	70.71 Mbps[352]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	99.2%[353]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	60%[354]	
	- 5G corridors	Thessaloniki, Sofia-Belgrade EL-BG-RS	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	proposed[355]	
	- 5G verticals (trials & initiatives	2 trials identified	

[351] Source: EC
[352] Greece's Mobile and Broadband Internet Speeds - Speedtest Global Index
[353] Source: DESI (5G readiness)
[354] Greece, July 2021, Mobile Network Experience Report Report | Opensignal
[355] Greece has reserved spectrum in 733-736 MHz and 788-791 MHz, 3400-3410 MHz, as well as 200 MHz from the higher 26 GHz band.

Other (indirectly relevant) targets[356]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	23.3%[357]	

5.1.13 Hungary

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 22 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	551[358]	
	- Network performance: speed	218.8 Mbps[359]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	61.1%[360]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	9.8%[361]	
	- 5G corridors	None identified	

[356] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[357] € 2.1 billion (development of 5G networks; digital transformation of public sector; digitalisation of businesses; digital transformation of education). Source: greece-recovery-resilience-factsheet_en.pdf (europa.eu)
[358] Source: EC
[359] Benchmarking the Global 5G Experience — September 2021 | Opensignal
[360] Source: DESI (5G readiness)
[361] Press-Details | Hrvatski Telekom d.d. (ht.hr)

-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials &) initiatives	1 trial identified	
Other (indirectly relevant) targets[362]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not approved yet	

5.1.14 Ireland

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 375 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	1,183[363]	
	- Network performance: speed	153 Mbps[364]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	30%[365]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[362] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[363] Source: EC
[364] Ireland, September 2021, 5G Experience Report Report | Opensignal
[365] Source: DESI (5G readiness)

urban areas and major roads and railways. (by 2025)	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	31%[366]	
	- 5G corridors	None identified	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	None identified	
Other (indirectly relevant) targets[367]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[368]	

5.1.15 Italy

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 1,180 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	No data reported	
	- Network performance: speed	47.51 Mbps[369]	

[366] Source: DESI (2020). Eir company declared that in November 2021 its 5G network covered 70% of the population (source: Eir to enable 5G on all mobile plans, at no extra cost (rte.ie))
[367] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[368] € 291 million (supporting the digitalisation of the public sector; digitisation of businesses; promoting digital skills). Source: com-2021-419-ireland_factsheet_en.pdf (europa.eu)
[369] Italy's Mobile and Broadband Internet Speeds - Speedtest Global Index

	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	60%[370]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	8.11% (overall) 0% rural[371]	
	- 5G corridors	Brenner Corridor IT-AT-DE[372]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	9 trials identified	
Other (indirectly relevant) targets[373]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	25%[374]	

[370] Source: DESI (5G readiness)
[371] Source: DESI (2020). Windtre company reported a population coverage of 40% (source: Italy, November 2021, 5G Experience Report Report | Opensignal)
[372] Home page - 5G CARMEN
[373] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[374] € 26.1 billion (development of ultra-fast and 5G networks; digitalisation of businesses; digitalisation of the public administration).
Source: italy-recovery-resilience-factsheet_en.pdf (europa.eu)

5.1.16 Latvia

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	circa 10 locations (Sept 2021 overview based on Ookla)[375]	
	- Number of base stations deployed (progress of deployments	58[376]	
	- Network performance: speed	45.29 Mbps[377]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	33.3%[378]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% rural[379]	
	- 5G corridors	5G-Routes (CAM, Rail, maritime) EE-LT-LV[380]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new	- specific provisions for verticals	None	

[375] For instance, Tele2 has already launched 5G mobile communication base stations in 15 Latvian settlements: Riga, Daugavpils, Jēkabpils, Jelgava, Jūrmala, Liepāja, Mārupe, Saldus, Salacgrīva, Sigulda, Talsi, Ogre, Olaine, Valmiera and Ventspils.
[376] Source: EC
[377] Latvia's Mobile and Broadband Internet Speeds - Speedtest Global Index
[378] Source: DESI (5G readiness)
[379] Source: DESI (2020); In 2021, Tele2 has already launched 5G mobile communication base stations in 15 Latvian settlements
[380] Home - 5g routes project (5g-routes.eu)

products, new manufacturing processes and new business models” by 2030	- 5G verticals (trials & initiatives	None	
Other (indirectly relevant) targets[381]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[382]	

5.1.17 Lithuania

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	1 (Vilnius)	
	- Number of base stations deployed (progress of deployments	110[383]	
	- Network performance: speed	63.03 Mbps[384]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[385]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% rural[386]	

[381] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[382] € 232.5 million: businesses digitalisation; digital upskilling; 5G deployment.
Source: latvia-recovery-resilience-factsheet_en.pdf (europa.eu)
[383] Source: Telia
[384] Lithuania's Mobile and Broadband Internet Speeds - Speedtest Global Index
[385] Source: DESI (5G readiness)
[386] Source: DESI (2020)

	- 5G corridors	- 5G-Routes (CAM, Rail, maritime) EE-LT-LV[387] - LT-PL Via Baltica Kaunas-Warsaw	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	1 trial identified	
Other (indirectly relevant) targets[388]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[389]	

5.1.18 Luxembourg

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 6 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	110[390]	
	- Network performance: speed	110.67 Mbps[391]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	60.8%[392]	

[387] Home - 5g routes project (5g-routes.eu)
[388] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[389] € 307 million: tailored technology for the Lithuanian language; customer-oriented services; 5G networks.
Source: com-2021-386-lithuania_factsheet_en.pdf (europa.eu)

[390] Source: estimation based on map. Source: Cadastre GSM - Geoportal Luxembourg (geoportail.lu)
[391] Luxembourg's Mobile and Broadband Internet Speeds - Speedtest Global Index
[392] Source: DESI (5G readiness)

-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% rural[393]	
	- 5G corridors	Metz-Merzig-Luxembourg FR-DE-LU[394]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	0 trials identified	
Other (indirectly relevant) targets[395]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[396]	

5.1.19 Malta

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in	- Urban areas covered (progress of deployments)	Circa 30 locations (Sept 2021 overview based on Ookla)	

[393] Source: DESI (2020); According to Orange, in 2021, 5G will be deployed all over the country
[394] 5GCroCo
[395] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[396] € 23.8 million: secure communications; digital services for public; digitise healthcare.
Source: luxembourg-recovery-resilience-factsheet_en.pdf (europa.eu)

one major city in all EU countries (by 2020)	- Number of base stations deployed (progress of deployments	282[397]	
	- Network performance: speed	62.10 Mbps[398]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[399]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% rural[400]	
	- 5G corridors	None identified	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives	0 trials identified	
Other (indirectly relevant) targets[401]	- Member States spending on to the digital priority (%Recovery and Resilience Plans).	26%[402]	

[397] 5G Trial Results - Melita Malta
[398] Malta's Mobile and Broadband Internet Speeds - Speedtest Global Index
[399] Source: DESI (5G readiness)
[400] Source: DESI (2020); nationwide coverage reported by Melita
[401] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[402] € 59 million: digitalisation of public administration and public services; digitalisation of companies; digitalisation of the justice system. Source: factsheet-malta_en_0.pdf (europa.eu)

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5.1.20 Netherlands

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 1,164 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	9,280[403]	
	- Network performance: speed	100.48 Mbps[404]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	33.3%[405]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	80% (overall) 29.1% rural[406]	
	- 5G corridors	Antwerp-Rotterdam-North Sea (Vlissingen) BE-NL[407]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	

[403] Source: EC.
[404] Netherlands's Mobile and Broadband Internet Speeds - Speedtest Global Index
[405] Source: DESI (5G readiness)
[406] Source: DESI (2020). At the end of October 2020, T-Mobile claimed that 90 per cent of the Dutch population lived within its 5G coverage area (source: https://www.t-mobile.nl/business/media/pdf/_netwerk/Report-P3-2020NL.pdf)
[407] 5G-BLUEPRINT ‹ 5G-PPP

“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	Proposed[408]	
	- 5G verticals (trials & initiatives)	4 trials identified	
Other (indirectly relevant) targets[409]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not submitted yet	

5.1.21 Poland

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 1,154 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	6,342[410]	
	- Network performance: speed	52.28 Mbps[411]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[412]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	10.3% (overall)	

[408] Plans to set aside 3750–3800 MHz
[409] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[410] Source: EC.
[411] Poland's Mobile and Broadband Internet Speeds - Speedtest Global Index
[412] Source: DESI (5G readiness)

		0% rural[413]	
	- 5G corridors	LT-PL Via Baltica Kaunas-Warsaw	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	Proposed[414]	
	- 5G verticals (trials & initiatives)	0 trials identified	
Other (indirectly relevant) targets[415]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not submitted yet	

5.1.22 Portugal

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	0 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	No data reported	
	- Network performance: speed	43.31 Mbps[416]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make	8.33%[417]	

[413] Source: DESI (2020). Polkomtel declared a population coverage of 40% (source: https://www.commsupdate.com/articles/2021/08/18/plus-5g-network-covers-over-15m-poles/)
[414] Considering allocation in 3.5 GHz
[415] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[416] Portugal's Mobile and Broadband Internet Speeds - Speedtest Global Index
[417] Source: DESI (5G readiness)

	these bands available for 5G		
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% rural[418]	
	- 5G corridors	Porto-Vigo, Evora-Merida PT-ES[419]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	2 trials identified	
Other (indirectly relevant) targets[420]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[421]	

5.1.23 Romania

Target	Indicator(s)	Performance	On Track

[418] Source: DESI (2020)
[419] 5G-MOBIX
[420] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[421] € 1.5 billion: vocational education and training institutions; digital health transition; digital transition of businesses. Source: portugal-recovery-resilience-factsheet_en.pdf (europa.eu)

-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 31 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	796[422]	
	- Network performance: speed	257.99 Mbps[423]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	21.3%[424]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	12% (overall) 0% rural[425]	
	- 5G corridors	None identified	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	2 trials identified	

[422] Source: EC
[423] Internet infrastructure | Invest Romania (gov.ro)
[424] Source: DESI (5G readiness)
[425] Source: DESI (2020)

Other (indirectly relevant) targets[426]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[427]	

5.1.24 Slovakia

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 6 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	260[428]	
	- Network performance: speed	51.49 Mbps[429]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	66.7%[430]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% rural[431]	
	- 5G corridors	None identified	

[426] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[427] € 2.8 billion: digitalisation of public administration; digitalisation of health; digitalisation of education. Source: factsheet-romania_en.pdf (europa.eu)
[428] Source: EC
[429] Slovakia's Mobile and Broadband Internet Speeds - Speedtest Global Index
[430] Source: DESI (5G readiness)
[431] Source: DESI (2020); O2 Slovakia’s launch is expected to have achieved 20% population coverage

-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials & initiatives)	0 trials identified	
Other (indirectly relevant) targets[432]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[433]	

5.1.25 Slovenia

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 40 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	266[434]	
	- Network performance: speed	57.52 Mbps[435]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[436]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[432] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[433] € 466 million: better services for citizens and businesses; digital infrastructure in schools; digitalising businesses. Source: slovakia-recovery-resilience-factsheet_en.pdf (europa.eu)
[434] Source: EC
[435] Slovenia's Mobile and Broadband Internet Speeds - Speedtest Global Index
[436] Source: DESI (5G readiness)

urban areas and major roads and railways. (by 2025)	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% rural[437]	
	- 5G corridors	None identified	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	No data reported	
	- 5G verticals (trials &) initiatives	0 trials identified	
Other (indirectly relevant) targets[438]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[439]	

5.1.26 Spain

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 4,065 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	7,510[440]	

[437] Source: DESI (2020); Telecom Slovenia reports 32% coverage of 5G
[438] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[439] € 241 million: strengthening digital literacy through education and life-long learning; digital health transformation; digital transition of businesses. Source: com-2021-384-slovenia_factsheet_en_0.pdf (europa.eu)
[440] Source: EC

	- Network performance: speed	28.14 Mbps[441]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	30%[442]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	13% (overall) 0% rural[443]	
	- 5G corridors	Barcelona-Perpignan, Santander-Biarritz ES-FR[444]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new products, new manufacturing processes and new business models” by 2030	- specific provisions for verticals	Proposed [445]	
	- 5G verticals (trials & initiatives)	16 trials identified	
Other (indirectly relevant) targets[446]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	28%[447]	

[441] Spain's Mobile and Broadband Internet Speeds - Speedtest Global Index
[442] Source: DESI (5G readiness)
[443] Source: DESI (2020); 75% population coverage according to Telefonica
[444] 5GMED – Future mobility in the Mediterranean Cross Border Corridor
[445] Reports for industry allocation in 26 GHz
[446] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.
[447] € 9.8 billion: digital skills training; digitalisation of public administration; digitalisation of business. Source: spain-recovery-resilience-factsheet_en.pdf (europa.eu)

5.1.27 Sweden

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in one major city in all EU countries (by 2020)	- Urban areas covered (progress of deployments)	Circa 60 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	No data reported	
	- Network performance: speed	273.5 Mbps[448]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	48.9%[449]	
-Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways. (by 2025)	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	14% (overall) 0% rural[450]	
	- 5G corridors	Nordic Way2 NO-SE-FI-DK[451]	
-all populated areas are covered by 5G by 2030 - -	- ***Populated areas covered (progress of deployments)*** - ***Population coverage*** -	***c.f. above***	
“digital technologies including 5G”….”at the core of new	- specific provisions for verticals	Implemented [452]	

[448] Benchmarking the Global 5G Experience — September 2021 | Opensignal
[449] Source: DESI (5G readiness)
[450] Source: DESI (2020). 16% population coverage by Three
[451] Nordicway2
[452] 3720–3800 MHz

products, new manufacturing processes and new business models” by 2030	- 5G verticals (trials & initiatives	3 trials identified	
Other (indirectly relevant) targets[453]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not approved yet	

[453] Other targets identified:
-all European households are covered by a Gigabit network, and
-In their Recovery and Resilience Plans, Member States are committed to dedicate at least 20% to the digital priority.

5.2 Workshop report

This document provides a summary of the 3rd European 5G Observatory Stakeholder Workshop – 5G in the Digital Decade, which took place on the 18th of November 2021 as an online event. The document is structure as follows:

- **Overview** – key figures and information about the event;
- **Agenda** – introducing the event structure and main topics covered;
- **Summary** – synthesis of presentations and highlights from open discussions.

3rd European 5G Observatory Stakeholder Workshop – 5G in the Digital Decade

18 November 2021 (10:00 – 14:30 CET)

Venue: online event

5.2.1 Overview

Title of the workshop: 3rd European 5G Observatory Stakeholder Workshop – 5G in the Digital Decade

Date: 18 November 2021, 10:00 -14:30

Place: online workshop

Number of attendees: 245

5.2.2 Agenda

10:00-10:10 **Welcome** *(Peter STUCKMANN, Head of Unit, EC DG CONNECT)*

10:10-10:30 **Opening** *(Pearse O’DONOHUE, Director, EC DG CONNECT)*

10:30-12:15 **Session I – What has been achieved? 5G is now reality in almost all the EU Member States – how were 5G Action Plan targets fulfilled and what have we learned?**

The session will discuss the current state of play of 5G deployment in Europe and globally, the latest market trends and how the COVID-19 pandemic has affected the sector.

IDATE, which conducted the European 5G Observatory for the Commission for the first two phases until June 2021, will present the main findings during the third year of the study. In particular, they will provide an overview of the progress towards the 5G Action Plan targets. A panel session will follow on challenges and opportunities for Europe in the next few years and the priorities to be addressed for different areas of 5G policy in light of global developments.

***Moderator**: Peter STUCKMANN*

Overview of latest 5G Observatory findings: *Stéphanie CHAR, IDATE (Contractor of European 5G Observatory Phases 1 and 2) and Patrisia COSTENCO, VVA (Contractor of Phase 3)*

***Panel Discussion** with the following panellists:*

Maarit PALOVIRTA, ETNO

Gabriel SOLOMON, Ericsson

Aarti HOLLA-MAINI, ESOA

Jonas WESSEL, RSPG

12:15-12:45 **Comfort break** (30 min)

12:45-14:30 **Session II – 5G in the Digital Decade. What are the prospects towards the full 5G target? What are complementary targets, e.g. for secure 5G deployment for vertical sectors? How to measure deployment progress and quality?**

The session will focus on the way forward and discuss priorities in light of the review of the 5G Action Plan and of the Digital Decade process. In particular, it will discuss the envisaged trajectory towards the full 5G target 2030 and complementary targets to monitor in Phase III of the 5G Observatory. It will also discuss promising areas of 5G policy to enable the investment during the recovery and throughout this decade.

In particular, this interactive session will discuss the following:

- Is the coverage of all populated areas by 2030 a sufficient target?

- How should a full 5G service be defined in terms of coverage and quality? How can it be monitored (number of base stations, population coverage/quality)?

- What are other aspects to be monitored (specific deployments for transport paths, industry 5G, smart cities and communities, tourism, agriculture,…)? How can those be monitored (kilometres covered, number of campus networks,…)

- How to monitor secure 5G deployment (advanced features such as 5G-SA core networks, supply markets, Open RAN,…)

- How to monitor green aspects such as 5G enabling green deal targets?

- What are the policy tools to facilitate investment in these priority areas?

Moderator: *Philippe LEFEBVRE, EC DG CONNECT*

Overview of feedback from targeted stakeholder surveys concerning 5G in the Digital Decade: Philippe LEFEBVRE

Initial plans for the European 5G Observatory Phase III:

Martin SIMS, PolicyTracker

Feedback Panel Discussion with the following panellists:

Erzsebet FITORI, Vodafone

Janette STEWART, Analysys Mason

Bo ANDERSSON, BEREC

Maxime FLAMENT, 5GAA

14:30 **Closure** *(European Commission)*

5.2.3 Minutes

5.2.3.1 Welcome and Opening

The workshop started with a welcoming speech by EC DG CONNECT. Before the start of Session I, the EC described the wider policy context in order to highlight the importance of monitoring 5G deployment for the European digital transformation:

- **EU Digital Strategy** seeks to establish a coherent and results-oriented framework to support the digital transformation for citizens and businesses in all sectors of the economy, and also to achieve the climate neutrality target set by 2050;
- EC underlined the importance of the **2030 Digital Compass Communication**, based on a vision for the European way towards the Digital Decade evolving around four cardinal points: Government, Skills, Infrastructure and Business;
- **The Digital Policy Programme** is supported by a system for progress monitoring, as well as a joint governance approach based on an annual progress reporting, prepared by the EC, and discussions on countries measures by the Council;
- The **5G Observatory** will play an even more important role in the future;
- Target for 5G: the aim is to avoid a fragmented deployment of 5G between Member States. Emphasis on **continuous cross-border 5G connectivity**;
- A clear visibility of **national milestones and measures** to meet the agreed targets is essential (recovery and resilience plans part of NextGenerationEU);
- **DESI (Digital Economy and Society Index)**: the overall platform for the annual monitoring of the Digital Decade targets. This will require different sources of supporting data. In terms of 5G monitoring, it is expected that the 5G Observatory will continue to collect relevant data useful for the annual monitoring in the context of the Digital Policy Programme.
- The deployment of 5G progressed well during last year and the target of having 5G launches in all the Member States was almost fully reached (two Member States missing). **The EC will support the countries who missed the 5G targets to better understand the potential issues and to address them**;
- Covid-19 affected 5G deployment to some extent;
- **5G Action Plan** goal: to reach uninterrupted coverage in all urban areas and along major transport paths by 2025;
- **New 5G** related **targets** are set for **2030.**

5.2.3.2 Session I

5.2.3.2.1 Overview of latest 5G Observatory findings

CHAR (IDATE): worked for the past 2 years on the 5G Observatory.

A summary on the scoreboards is presented, covering the period from June 2019 to June 2021:

- 25 countries out of 27 with 5G commercial services;
- 45.8% of the spectrum assigned in EU27, mostly in lower and mid bands. Still looking for deployment in the high bands, 26 GHz in particular;
- 12 5G cross-border corridors;

- In terms of 5G spectrum, in comparison with other countries across the globe, Europe is well positioned in lower bands and mid bands. Not all countries adopted the 700 MHz spectrum as a 5G technology;
- In mid band, EU is also well positioned in the comparison with other countries such as China, Japan, and USA.
- Commercial launches:
    - 5G service in 25 MS markets
    - Almost all countries used 3.6 GHz, while some used 2.1 GHz
- Market deployment; 3 categories:
    - small scale deployment: using 100s + cell sites (EU as a whole)
    - medium scale deployment: using 10,000s + cell sites (USA, Japan and Germany)
    - large scale deployment: 100,000s + cell sites (China, South Korea)
- 5G usage: phones are 51% of 5G devices in the market as of June 2021, followed in descending order by the CPE, modules, hotspots, switches & routers, laptops, tablets, and other devices (e.g. connected glasses)
- Slow adoption of 5G: no 5G killer app so far
- 5G services pushed by the Covid-19: virtual office, remote school, health services
- In terms of spectrum assignment, there are disparities among Member States

COSTENCO (VVA): A summary on the scoreboards (EU 27 and international) until October 2021 is provided:

- In the next quarter, expected developments in the use of 5G in terms of both, integration for transport services and commercial launches;
- Spectrum assignments: today the majority of Member States have assigned at least one 5G band;
- Several operators in the EU have been launching standalone access 5G networks, but non standalone configuration still dominates existing commercial services;
- Base stations: China has nearly one million 5G base station, which is nearly nine times more than the EU, and eighteen times more than USA;
- China hosts the largest base of 5G subscribers;
- Spectrum assignments (international context): all major economies have been assigning the low bands spectrum in the 600 MHz or 700 MHz, except for South Korea and Japan;
- Mid band spectrum has been important for 5G (assigned in all major markets);
- High frequency bands: the initial enthusiasm for 26 GHz assignments has been peaking (lack of assignments across the EU).

5.2.3.2.2 Panel discussion: opening remarks

PALOVIRTA, ETNO:

- 5G deployment from an operator’s perspective: data and numbers are evolving very fast
- 5G penetration in Europe (uptake): in 2020, 1.5% across Europe; 7% in 2021; in 2022 forecasted to reach 18% (early State of Digital Report Data forthcoming January 2022);
- Coverage numbers: There is still a gap between the availability of 5G services and the uptake (e.g. 25% coverage in Europe end of 2020);
- 5G starting to be commercially available in most Member States;
- By 2025: a third of Europe of coverage (ETNO-GSMA report);
- In 2025: EU slightly behind USA and China;
- 2025-2030: a lot of work foreseen to reach the target;
- The meaning of 5G for users: mobile broadband access is still the main use case for 5G. Vertical use cases: not seen yet the impact at scale across Europe
- Some of the use cases will be country specific
- Key elements for 5G development:
    - Spectrum: efficient and effective spectrum policy licensing;
    - Open mind approach on new business models and new deployments models;
    - ICT and telecom suppliers and vertical industries: cooperation is fundamental. The European scope is key, need to pool resources together. Competition policy needs to be aligned to support this;
    - Collective responsibility;
    - Security and environmental sustainability.

SOLOMON (Ericsson):

- Welcomes the holistic approach taken by the Digital Decade: 5G can underpin Europe’s digital transformation and contribute to decarbonisation
- Recent research shows that expanded connectivity solutions across 4 sectors, power, transport, manufacturing and construction, could reduce EU emissions by 15% by 2030 and by up to an additional 5% if 5G deployment is accelerated
- On the demand side: the 5G aligns for connected industries in automation in sharing the momentum (5G-ACIA);
- 2 main points to achieve the 2030 target and deliver step change in performance:
    - 5G standalone
    - Massive MIMO on mid-band
- Survey: half of the operators plan to deploy standalone networks by next year, and 90% by 2023;
- Mid band deployment expected to be slower: early intervention from policymakers required to enable transformation.

HOLLA-MAINI, (ESOA):

Introducing context:

  - Progress on Non-Terrestrial Networks (NTN) standard work by 3GPP in collaboration with mobile operators will bear fruit with completion of Release 17;
  - Mass market uptake vs. high network deployment costs (ROI);
  - Energy consumption: higher energy consumption and more dense deployments expected with 5G;
- There is a need to optimise network deployments (incorporating satellite technology into the mix when deploying);
- Satellites sector trials and demos by the industry, involving terrestrial players;
- 3 aspects to be observed:
  - All of the use cases are driven by the need for coverage/reach and are relevant for mass market applications
  - Majority of the trials are market-driven and many of them involve terrestrial players
  - Taking place across all satellite orbits (GEO/MEO/LEO)
- Important areas of activity:
  - Enhanced mobile broadband: to provide enterprise services for hard-to-reach business communities; emerging LEO broadband operators
  - Cloud computing
  - Mobility solutions being tested using 5G NTN specs (Connected & Autonomous Vehicles - CAVs) and being explored for future mobile communication system (FRMCS) for railway operators
  - Security for satellites connections is higher than terrestrial due to fewer nodes of entry
- Holistic approach (convergence of technologies and aerial view) required from policymakers for 5G and 6G.

WESSEL (RSPG):

- 5G Observatory: important to measure the right things
- What is 5G really?
  - Boundaries of parameters: DSS/NSA/SA, multiple networks
  - **Services**
- RSPG/policy perspective: starting point to clarify that 5G needs low, mid and high bands;
- Progress has been made (5G Observatory reporting on spectrum awards);
- Next step following harmonisation/standardisation: making spectrum available
  - EC monitoring MS (naming and shaming can act as an incentive)
  - Technology frontier
- Role of regulators: to create the playground for operators and users, “killer applications” will follow.

5.2.3.2.3 Panel discussion

- High-band and market readiness: technology frontier without clearly defined demand (specific applications vs. spectrum demand); ecosystem readiness, new revenue opportunities and business case for wide area deployment vs. verticals/emerging sector applications:
    - Operator’s perspective (PALOVIRTA, ETNO):
        - Chicken and egg problem
        - Business reality: demand is lagging behind coverage and operators do risk calculations when launching 5G service.
        - Auctions and licensing: nationwide individually license solution as general principle, as most use cases can be served through the general spectrum.
        - 26 GHz: in terms of licensing, some of the spectrum could be given to local networks.
- On the opportunities brought by Standalone 5G/Open Innovation Platforms (SOLOMON, Ericsson):
    - We are in the middle of a transition. From a commercial perspective, a lot operators are uncertain on the rules.
    - In terms of deployment, operators have to be governed by economics. One opportunity is to focus on energy and logistics sectors with high state presence to pull through investments. If we create demand, people will invest.
- Energy consumption vs. energy efficiency for network deployment (including densification and capacity vs. coverage):
    - Satellite perspective (HOLLA-MAINI, ESOA):
        - Multiple priorities, objectives and targets - requires holistic approach: important to point out that it is not possible to address challenges separately. Should be a priority to address energy efficiency, capacity and reach together and we have the technology to do this. Requires more coordination.
        - Time to celebrate will not be when the coverage is available in all major cities of EU, but when the majority of EU citizens are covered by 5G.
    - Regulator’s perspective (WESSEL, RSPG):
        - If the only 5G bottleneck is market demand this is an improvement: all other barriers to deployment/uptake experienced by previous generations (lack of spectrum, terminals have been addressed.
        - Modernisation of networks is a huge part of reducing energy consumption (2/3G network sunsets).
        - RSPG approving an Opinion on climate change in next meeting
    - Industry perspective (SOLOMON, Ericsson):
        - It is underlined that 5G is the most energy efficient solution ever. In 2025, generally in Europe energy will be carbon neutral. 5G will enable to reduce carbon emissions and to have more devices connected.
    - Operators’ perspective (PALOVIRTA, ETNO):
        - networks will help society to become greener (greening of networks vs. greening by networks)
        - aligned with vision (incentive to become more efficient and cut energy costs)
- Wholesale trend in tower companies (WESSEL, RSPG):
    - Policy perspective: promote peer-review-process among MS

5.2.3.3 Session II

5.2.3.3.1 Overview of feedback from targeted stakeholder surveys concerning 5G in the Digital Decade:

LEFEBVRE, EC

- Future 5G vertical use case:
  - for each of the expected use cases, there is no obvious killer application yet but a lot of expectation.
  - However, operators expect a potential of only 10 to 20% in revenue from vertical use cases
  - Vendors expect 30%-50% increase in revenues
  - Almost all stakeholders expect a wide range of vertical use cases to reach commercial deployment by 2025
- Network deployment needs:
  - Stakeholders expect a comprehensive deployment of high quality 5G networks
  - Most connectivity types needed where people live, work, and travel, including along transport paths
  - Possible need to cover all reachable landmass for some machine-to-machine (M2M) and some mission-critical applications (e.g. PPDR)
  - 5G coverage for drone corridors is a realistic prospect, but nearer to the end of the decade
- Infrastructure investment needs:
  - Stakeholders consider that the Commission’s projected investment gap is underestimated
  - Stakeholders estimate the infrastructure investments for vertical use cases are about 7 to 10 times lower than for the open public infrastructure
  - Due to their local nature and the early market status, investments in Private networks are considered as marginal when compared to wide-area network investments by consulted stakeholders
- 5G Deployment Targets:
  - Majority in favour of common EU deployment objectives for 2025-2030
  - But same stakeholders think that existing targets are sufficient for now:
    - 2025 target of 5G coverage in all urban areas and where people work
    - 2025 target of uninterrupted 5G coverage along many transport paths
    - 2030 target of 5G coverage of all populated areas
  - About a half of respondents still favourable to additional targets to be considered at a later stage, possibly: regarding progress of vertical use cases; level of network security; contribution to green policies; in relation to transition from copper to fibre; in view of 6G
- Market trends
  - Trends influencing investment paradigms
    - 6 trends with comparable impact (several of them of a potentially disruptive nature)
      - Convergence of cloud and connectivity services
      - Large-scale deployment in challenging areas (e.g. along highways and rail)
      - Use of public networks for vertical use cases
      - Open RAN/open network technologies

        - Convergence fixed networks/mobile backhauling infrastructures
        - Large scale deployment of very dense cells
    - Most investment-conductive models
        - A range of “sharing” approaches expected to grow significantly
        - Regulatory changes desired by market players in some areas
        - However, several operators would welcome specific competition and technical criteria so they could avoid the ex-post risk of network-sharing agreements that violate EU antitrust rules
    - Barriers to cross-borders take-up of 5G services
        - Three quarters of respondents see major barriers for the take-up of pan-European services, starting with CAM and IoT
        - Majority supports the development of cross-sector **Strategic Deployment Agendas** under EC leadership
        - About half of respondents agree that public financing of cross-border facilities should stimulate additional private investments (about 40% without opinion)
- Spectrum roadmap
    - EU spectrum coordination
        - Across-the-board support for: enhanced EU coordination regarding spectrum authorisation rules; coordination of spectrum re-farming also enjoys clear support
        - New suggestions, at least mentioned multiple times: consider spectrum policy intervention framework similar to Art. 32 (ex Art. 7 procedure) of the European Electronic Communications Code; ensure national challenging compatible with standards
    - Freeing spectrum through switching off 2G/GSM
        - No call for fixed date for the switch-off of 2G/GSM across Europe any time soon
        - However, widespread recognition of the spectrum cost of 2G legacy and risk of delays in market-driven phasing-out due to competing marketing strategies
        - Facilitating role of EC would be supported by two thirds, including some main associations and operators
    - Spectrum (re) allocation issues
        - Top re-farming opportunities (mostly based on 5G substitution, except military)
            - Military use (2.3 GHz)
            - Terrestrial broadcasting (600 MHz)
            - PMSE
            - PPDR
            - Applications operating in 380-400 MHz, 410-430 MHz, 450 MHz, 3800-4200 MHz
        - Spectrum verticals
            - Clear opposition of views between established operators and vendors
            - Operators wish that proper Impact Assessment be conducted before allocating spectrum to vertical use cases
    - Future spectrum bands

        - Operators call for more flexible use of lower UHF spectrum (DTT) well before current 2030 deadline
        - Converging views regarding targeted mid bands
        - No consistent views on additional spectrum above 10 GHz, beyond the pioneer 26 GHz band. Many see this need as only being applicable in the context of 6G
- Transition to secure 5G networks: clear transition periods and regulatory stability are essential
- Green policy and 5G:
    - Several important players and industry associations are in favour of EU targets for meeting the green policy objectives
    - Most widely supported candidate areas for common targets: energy consumption of 5G infrastructure; greenhouse gas emissions of 5G network components; use of renewable energy; material footprint
- EMF exposure:
    - Support for EU-level cooperation, especially possible binding “common EMF limits”
    - Interest in EU coordination for consistent implementation of EMF measurement methodologies

5.2.3.3.2 Initial plans for the European 5G Observatory Phase III

SIMS, PolicyTracker:

- Goals of the 5G Observatory:
    - online repository of market developments
    - third-party assessment of the 5G Action Plan and relevant Digital Decade targets
- Other 5G-related policy goals
    - 5G Cybersecurity Toolbox implementation
    - Digital Decade: role of 5G and other technologies in digital transformation
    - Electronic Communications Code: urges harmonised approach to EMF limits
- The website has been updated to reflect these new policy goals. All information collected in the previous study phases and made available via the website is available in the archive section.
- Monitoring progress towards new policy goals: national and EU-wide analysis
- In terms of what is holding back regulators release of access to 26 GHz across Europe, few countries underlined that there has not been urgent demand from operators

5.2.3.3.3 Panel discussion: opening remarks

FITORI, Vodafone, (operator perspective):

- Digital Decade targets: Vodafone very supportive towards these (ambitious) targets
- On 5G: All populated areas need 5G
    - Advocate for truly transformational 5G to meet the targets. This can genuinely transform European industries and sectors (health, agriculture, public sector among others).
    - 40-45% transformational coverage in the US: comparable parameter for Europe is around 14%.

- In terms of the Digital Policy Programme: very important to have a shared perspective, mutual understanding and common support among Member States.
    - Monitoring, feedback loops are also equally important.
- Policy enablers: private and public investment in 5G.
- Use cases for truly transformational 5G: telemedicine, rural areas/agriculture, autonomous mobility.

STEWART, Analysys Mason:

- By the end of the decade we will enter into a cloud driven world, with a rapid pace of change.
    - By 2030, a network of networks (satellite, WiFi, sensor technologies all working together)
    - Cloudification: requires radical changes to the way networks are designed
    - Investment to shift towards horizontal digital infrastructure: open network platforms, multiple cloud domains, network enterprise edge
    - SA to provide foundation for most advanced version of 5G services
    - Public mobile core networks, NFP and cloud networks potentially running side by side
        - Virtual infrastructure management
- Private (LTE/5G) networks: on premise or hybrid deployment with MNOs
    - Interesting to track evolution in the coming years (around 100 deployments in Europe, increasing share using 5G)
- Is coverage of all populated areas by 2030 a sufficient target?
    - Populated areas coverage has been a challenging way of measuring coverage to date
    - 5G technology is used in different sectors and industrial applications: could mean that coverage would need to be understood on an area or geographic basis
    - Quality of 5G coverage depending on deployment type is relevant to be monitored: e.g. 3.5 GHz roll out vs. low frequency. 3.5 GHz rollout to 60% of existing macro sites in European markets: less than 20% of geographic coverage and 70% population coverage in the UK.
    - **A more holistic approach on coverage of the population is needed:** to give information to the market. Not all economic sectors will need 5G: next generation of satellite solutions will be important to achieve coverage and resilience.

ANDERSSON, BEREC, public body representative:

- Co-chair working group on wireless network evolution:
    - One of the elements we are looking at is how to gather information for consumers
- BEREC undertaking various activities on the topic of 5G in the past years:
    - Feasibility study on the development of coverage information

  - Quality service parameters
  - Handbook of Guidelines on Geographical surveys of network deployment (mobile service mapping and fixed infrastructure mapping)
  - Guide for 5G radar

- Mapping of 5G network coverage: theoretical estimates vs. quality of service (signal strength measured by NRAs in different areas) vs. Quality of experience (consumers perspective)
- Meaningful coverage maps for 5G services: usable by operators, meaningful for end users, verifiable by NRAs.
  - 5G can mean different things for different end users
- December summary report from workshop on 5G experiences planned to be published.
  - Challenging to do mapping in a representative way
  - Metrics are an essential ingredient of the Digital Policy Programme.

FLAMENT, 5GAA, vertical for automotive:

- Interesting to monitor quarterly developments via 5Gobs reporting
- Key indicators from one vertical are not always the same for other verticals
- Potential contribution from 5GAA to 5G Obs progress tracking: to integrate vertical specific indicators and challenges:
  - Km of highways/roads covered by 5G
  - number of registered vehicles that are connected and have capabilities to exchange data: not easy to monitor this at global level (base station per vehicle)
  - One metric to be analysed is the km of highways/roads covered by 5G
- Uncertainty present in some of the European markets (Europe), mostly related to some technology building blocks related to 5G standards, mainly the integration of the connectivity of the vehicle to its cloud/service through the mobile network, but also connected to other vehicles via device-to-device direct communication
- Important to address pain points experienced by both OEMs and road users: low service coverage areas
- An important goal to achieve is seamless cross-border connectivity: 5G corridors.

5.2.3.3.4 Panel discussion

Round 1:

What are the key flavours for 5G and how this is related to coverage targets (population coverage by 2030)? Should we have additional policy targets, like for example in the area of green policy or security? Now or only in the future? Which ones?

What are the implications for metrics: should reporting take place per type of spectrum bands?

Vertical perspective (FLAMENT, 5GAA):

- urban level/dense area metrics are quite easy to agree on: resources are shared among vehicles and verticals. 5G corridors: rail, road: metrics should be adapted to services. Operators should already know they quality across transport paths.

Regulator’s perspective (LEFEBVRE, EC):

- obligation for MS reporting (part of Digital Policy Programme) could cascade to MNOs.

Operator’s perspective (FITORI, Vodafone):

- A policy toolbox for Member States may be needed to help them to reach set targets. Support private investment in 5G, providing a clear legal basis (similar to RSPG).

Policy perspective (LEFEBVRE, EC):

- Integral part of Digital Policy Programme: peer review
- National roadmaps: reforms and regulatory measures including investment plans (MS to disclose amount of investment committed to financing infrastructure).

Question on need of reporting on private networks where advanced 5G services could be more likely to appear (vs. public networks):

- STEWART, Analysys Mason: Yes, useful and relevant market information to be tracked: EU is ahead in this area, lot of private networks using 3.8-4.2 GHz in the UK, 3.7-3.8 GHz in Germany. Increasing trend towards 5G.
    - Interesting to track how bands are used for private deployments
    - Operators are often involved in deployments. Relevant to report information such as contractors, frequency band, country, sector.
- ANDERSSON, BEREC: Since there is no killer application, and in the context expected growth of industrial applications, from a regulatory perspective there is a need to facilitate efficient use of spectrum. Case by case applications needed for networks/users. Importance of peer-review/learning for NRAs.

FLAMENT, 5GAA: Automotive perspective on Edge computing: it is a mean to an end, not an end by itself. Something to be exploited. For the automotive sector, one of the most challenging uses of the edge computing is the multi MNO requirement when all the vehicles must be able to use it. This creates this multi-brand and multi-cross OEM aspects. It will come very gradually, still couple of years ahead.

Question from audience: A common classification of 5G deployments would be extremely useful: A repository of frequency, use of DSS, SA/NSA… ranked by performance & investment needed. Distinguish ‘cutting edge’ 5G from ‘cheap’ 5G.

Reformulated: We could report number of base stations per capita for different spectrum bands. What is the next step? Mapping with some simple QoS categories e.g. latency or minimum capacity? Is it realistic and when? 2-3 years? Is it the next step?

- STEWART, Analysys Mason: Question whether it is feasible to get this information gathered. More information on frequencies deployed is very useful information, also gives information on quality of service throughput. E.g. using DSS typically implies uplink speed slower for wider cell area: so number of 3.5 GHz deployments is not sufficient: missing information on throughput on uplink. Combination of information about frequency band per site, configuration (DSS/SA across entire network or selected sites), would be quite helpful.
- FITORI, Vodafone: Quality of service (theoretical) reporting per operator: to a certain extent are able to measure, challenging question to be answered. Given that certain licences already include obligations: reporting to NRAs already taking place.

5.2.3.4 Closure

EC underlined 5G reporting will follow in the next iterations in the most pragmatic possible way.