EUROPEAN COMMISSION

Directorate-General for Communications Networks, Content and Technology

5G Observatory

Quarterly Report 13

Up to October 2021

Quarterly report

October 2021

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1 Executive summary

1.1 Introduction

This is the thirteenth quarterly report of the European 5G Observatory for the third quarter of 2021.

At the end of October 2021, 5G commercial services were available in twenty-five of the EU-27 countries.

Compared to previously communicated results, some progress has been recorded in terms of the level of spectrum assignments in the pioneer bands. However, the 5G Action Plan objectives set for the three pioneer bands have not been achieved in all Member States yet. At the end of June 2021, five Member States had made available and assigned spectrum in all three pioneer bands, whereas in October 2021 there were seven Member States reporting such progress.

Auctions have been restarting after the pandemic delays, and only seven Member States have failed to assign any pioneer bands to date.

1.2 Status of 5G deployment in Europe and assessment against the Digital Decade targets

National administrations in the EU have taken measures to facilitate the introduction of 5G over the past 5 years which includes national 5G strategies[1] and completion of 5G spectrum assignments.

A number of Policy initiatives have been undertaken by the EU to boost the deployment of 5G infrastructures and services across the Digital 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.[2]

In March 2021, the European Commission set targets for the digital transformation of the bloc by 2030 in their Digital Decade announcement.[3]

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.[4] As a complementary

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

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.

The table below summarises the overall performance of EU27 against relevant 5G-related targets sourced from EU Policy programmes introduced above.

Targets: 5G AP; Digital Decade; Cybersecurity Toolbox	Performance/status
Commercial launch of 5G services at least in one major city in all EU countries	By 2021 there had been commercial 5G launches in all EU countries, with two exceptions: Lithuania and Portugal. All deployments to date across 25 Member States cover major cities and urban areas.
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%.[5]Fragmented data is available on coverage of urban areas per MS whereas information on 5G coverage of roads and railways is almost non-existent (exception Finland).
“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 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. Nineteen out of 27 Member States have assigned this band. The second most popular band is the 700 MHz band, which has been assigned in 17 out of 27 Member States. The least popular band is the 26 GHz band, which has only been assigned in seven Member States. Finally, seven 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
Promoting pan-European multi-stakeholder trials (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.[6]
5G toolbox implementation	A large number of Member States have already taken concrete steps to implement the various strategic measures. [7]

[5] 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
[6] CZ, ES, IT, LV, EL, LT plans.
Source: Commission Staff Working Document
[7]https://digital-strategy.ec.europa.eu/en/library/report-member-states-progress-implementing-eu-toolbox-5g-cybersecurity

Overall, 52.7% of pioneer bands have been assigned, with the following breakdown per band:

- 700 MHz: 61.1% % assigned and 38.9% not assigned.
- 3.6 GHz:: 70.9% assigned, 29.1% not assigned.
- 26 GHz: 25.9% assigned, 74.1% not assigned

1.3 Strategic implications

Referring to the overall performance of EU27 against relevant 5G related targets, the table below outlines major strategic implications based on findings to date. This monitoring and recommendations exercise will represent the basis for a full strategic discussion including roadmap to be included in the final report:

Bottlenecks identified	Solution/recommendation
Countries with no commercial service launched to date i.e. Lithuania and Portugal.	Investigating the root cause of the issue to launch commercial service is a first step to potentially solve it. In the case of Portugal, the multi-band spectrum auction took an exceptionally long time and only ended on 28 October after 201 days of bidding.[8] This was after ANACOM had taken measures to speed up the process such as increasing minimum bidding increments and number of daily bidding rounds. [9] For Lithuania, the auction for pioneer bands is yet to start.[10] The regulator RRT expects to announce the frequency auction very soon (after signing a memorandum among public sector institutions and mobile operators on 5G development)[11]. One of the biggest obstacles pointed out by the regulator have been the negotiations with bordering countries (e.g. Russia) on the release of the priority 3.5 GHz frequency band. RRT therefore expects commercial launch is in Vilnius by 2022[12] and trials have already been carried out by some operators within existing spectrum holdings.[13]
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.[14, 15]

[8] https://www.anacom.pt/render.jsp?categoryId=416583
[9] https://www.policytracker.com/blog/the-agony-continues-in-portugals-record-breaking-auction/ and https://www.policytracker.com/portugal-raises-over-e560-million-in-longest-ever-auction
[10] https://www.rrt.lt/en/public-and-private-sectors-agreed-on-actions-regarding-5g-connection-in-lithuania/
[11] https://www.rrt.lt/en/public-and-private-sectors-agreed-on-actions-regarding-5g-connection-in-lithuania/
[12]https://kaunas.kasvyksta.lt/2021/10/12/mokslas-ir-it/5g-rysys-lietuvoje-bus-diegiamas-3-etapais-pirmasis-aukcionas-po-dvieju-savaiciu/
[13] https://www.telia.lt/pranesimai-spaudai/telia-is-launching-5g-network-in-lithuania
[14] Source: Proposal for a Decision establishing the 2030 Policy Programme "Path to the Digital Decade"
[15] For more information regarding 5G targets in the digital decade see: https://digital-strategy.ec.europa.eu/en/policies/5g-digital-decade

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.
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.[16]
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.
Based on the latest NIS report (2020), there are visible differences in terms of implementation maturity for different types of individual measures.[17]	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).

1.4 Conclusions and next steps

This thirteenth quarterly report of the European 5G Observatory for the third 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 next steps and updates to be presented in the following publication include improvements in terms of indicators and scope of information covered for the European and international scoreboards, forecasting activity to anticipate EU 27 progress towards the achievement of EU Policy (5G AP and Digital Decade Targets):[18], consultations with industry representatives and feedback collected from the 3rd European 5G Observatory Stakeholder Workshop.

[16] 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.
[17] https://digital-strategy.ec.europa.eu/en/library/report-member-states-progress-implementing-eu-toolbox-5g-cybersecurity
[18] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2021:0247:FIN:EN:PDF

2 Overview of recent major developments

Chapter 2 presents a brief (partly visual) summary of EU-27 and overview of comparable international trends.

Focusing on the European dimension, progress has been recorded over the past year to enable additional deployments, including spectrum assignments in EU-27. The European Commission’s 5G Action Plan (COM (2016) 588) targeted commercial launch of 5G at least in one major city in every Member State by the end of 2020 as well as uninterrupted 5G coverage in all urban areas and major terrestrial transport paths by 2025. These targets will pave the way towards the new ambitious European approach to a digitalised economy and society, presented in the 2030 Digital Compass Communication “The European way for the Digital Decade” (COM (2021) 118). Specifically for 5G, the Digital Decade strategy sets to achieve 5G coverage of populated areas by 2030.

2.1 Summary of recent developments

This section outlines developments in both the EU and internationally since the publication of the last 5G Observatory Quarterly report in June 2021.

2.1.1 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 in the last five months:

- July 2021: Spain completed its 700 MHz auction, raising over €1 billion Euros.[19]
- August 2021: Croatia completed its 700 MHz, 3.6 GHz, and 26 GHz auction. It raised a total of €47.9 million Euros.[20]
- October 2021: Portugal completed its 700 MHz, 900 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz and 3.6 GHz spectrum auction, which raised a total of €566 million Euros.[21]
- October 2021: Malta completed its award of the 3.6 GHz band. This was granted to operators through a direct assignment process.

In the EU procedures are being finalised for Romania and Lithuania’s 5G auctions. Romania’s 800 MHz, 2.6 GHz and 3.5 GHz qualified to bid stage began in October and the deadline for

[19] https://5gobservatory.eu/spain-raises-over-1-billion-eur-in-700-mhz-auction/
[20] https://5gobservatory.eu/croatia-completes-5g-spectrum-auction-new/
[21] https://www.policytracker.com/portugal-raises-over-e560-million-in-longest-ever-auction/

submission is November 15.[22] In Lithuania, the regulator released detailed information about their award of the 700 MHz band in October. The auction is due to take place in Q1 2022.[23]

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

- July 2021: Canada completed its 3.5 GHz 5G auction, raising a total of €6 billion Euros.[24]
- October 2021: Norway concluded its 5G auction in the 2.6 GHz and 3.6 GHz bands. It raised a total of €49 million Euros.[25]
- October 2021: The Dominican Republic concluded its 700 MHz and 3.3GHz - 3.4GHz band auction, raising a total of €63 million Euros.[26]
- October 2021: Hong Kong completed its 5G auction in the 600 MHz, 700 MHz, 850 MHz, 2.6 GHz, and 4.9 GHz bands. It raised a total of €210 million Euros.[27]

In the United States, the 3.45 - 3.55 GHz auction is currently in progress. It began on October 5.[28] Furthermore, Brazil’s 700 MHz, 2.3 GHz, 3.5 GHz and 26 GHz auction is due to take place November 4.[29]

2.1.2 Policy

In September 2021, the EU Commission announced the Path to the Digital Decade.[30] This proposal sets out a concrete plan to achieve the previously announced targets in the Digital Decade. This proposal sets out various ways of achieving the ambitious digital transformation targets set out in the previously announced Digital Decade initiative. This includes the production of a report that monitors Member States progress towards Digital Decade 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 in the Path to the Digital Decade.

There appears to be continued interest in local 5G licensing models. In South Korea, the Ministry of Science and ICT (MSIT) announced in October that it is slimming down the review process for

[22] https://www.ancom.ro/ancom-lanseaza-licitatia-pentru-noi-licen539e-de-spectru-destinat-serviciilor-de-comunica539ii-mobile_6378
[23] https://www.rrt.lt/en/rrt-announces-an-auction-for-granting-the-right-to-use-radio-frequencies-from-the-700-mhz-radio-frequency-band/
[24] https://5gobservatory.eu/canada-completed-its-3-5ghz-5g-auction/
[25] https://www.nkom.no/aktuelt/the-norwegian-5g-auction-has-concluded
[26] https://www.commsupdate.com/articles/2021/10/14/dominican-republic-5g-auction-raises-usd74m-claro-altice-share-the-spoils/
[27] https://www.ofca.gov.hk/en/news_info/press_releases/index_id_2274.html
[28] https://www.fiercewireless.com/regulatory/fcc-3-45-ghz-spectrum-auction-keeps-chugging-price-above-21b
[29] https://www.reuters.com/technology/brazil-sets-5g-mobile-auction-nov-4-says-minister-2021-09-24/
[30] https://ec.europa.eu/commission/presscorner/detail/en/QANDA_21_4631

companies who want to deploy a local 5G network. This is to encourage the deployment of local 5G applications such as verticals and private networks.[31]

Sweden’s telecommunications regulator PTS on the other hand has expressed interest in a local 5G license model. It issued a consultation about proposed local 5G licenses in the 3720–3800 MHz and 24.25–25.1 GHz bands.[32]

In the EU progress has been made towards harmonising the EMF limits for the deployment of IMT base stations, an issue which is particularly relevant for 5G. The Brussels regional government approved a higher GSM radiation limit in August, which will enable the rollout of 5G in the city. Although this new limit allows for the use of 5G base stations, it is still more restrictive than the EU-recommended ICNIRP (International Commission on Non-Ionizing Radiation Protection) limit.[33] EMF limits in other parts of the country vary by region.

2.1.3 Commercial launches

In the EU operators have already launched 5G in all but two countries, and networks are continuing to expand. For example, O2 Slovakia launched commercial 5G services in 15 towns and cities in September.[34] In the richest nations like the USA, Japan, South Korea and China, commercial 5G services have been in operation for a couple of years, and 5G is now spreading to less developed countries. In Indonesia, despite a small amount of available spectrum, telcos Telkomsel and Indosat Ooredoo launched their 5G services in July.[35]

Several European mobile operators have announced 5G population coverage numbers. In early September, Telekom Germany announced that its 5G network covers 85% of Germany’s population with 5G.[36] Furthermore, Irish telco eir announced it now reaches 70% of the country’s population with 5G services.[37] Finally, T-Mobile Poland has announced that it covers 25% of the country’s population with 5G.[38]

2.2 5G scoreboard

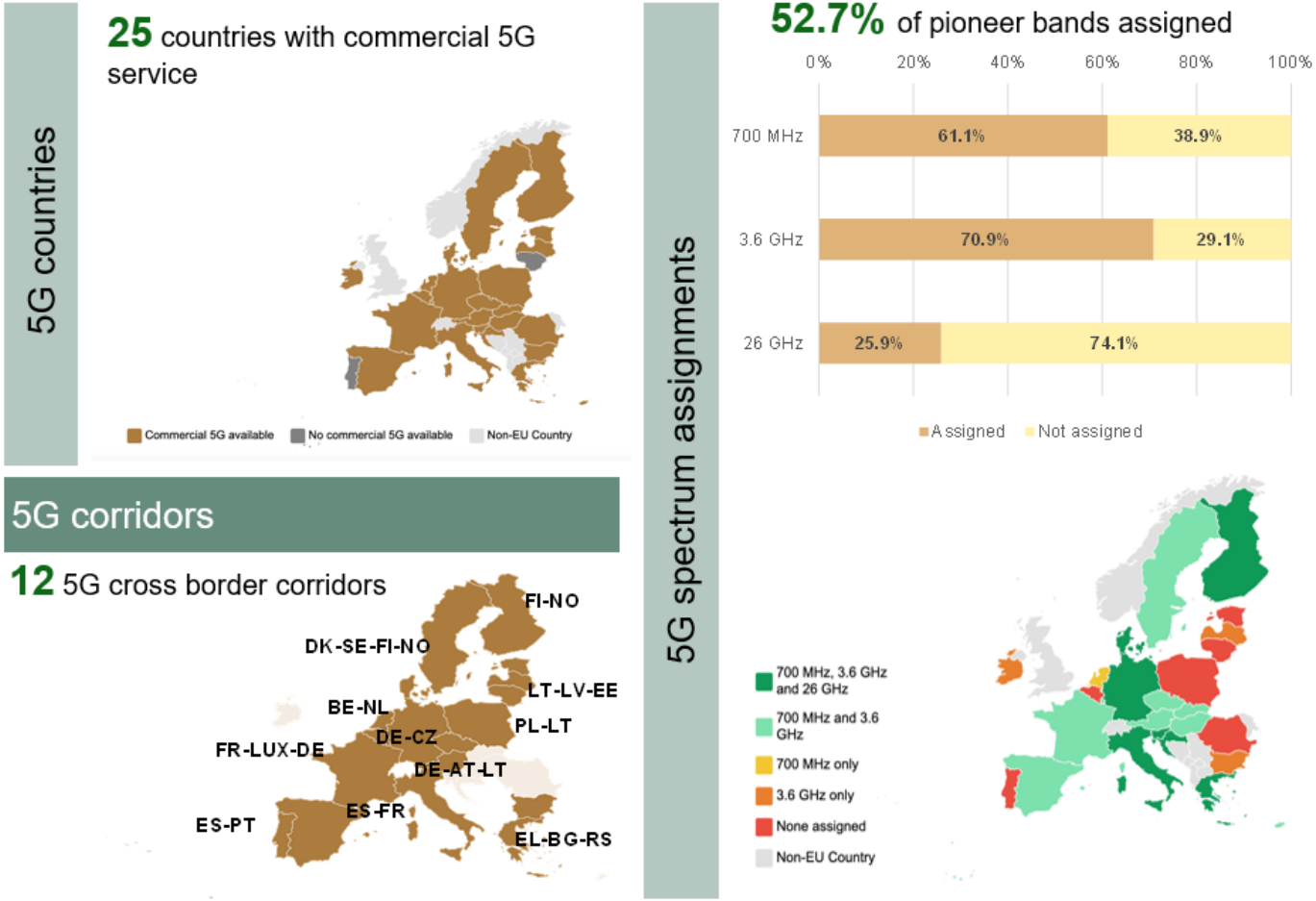
2.2.1 EU27

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

[31] https://www.policytracker.com/south-korea-slims-down-bureaucracy-for-local-5g/
[32] https://pts.se/sv/nyheter/radio/2021/pts-har-tagit-fram-forslag-till-villkor-for-lokala-5g-tillstand/
[33] https://www.policytracker.com/brussels-gets-5g-friendly-emission-limits-for-base-stations/
[34] https://spolocnost.o2.sk/pre-media/o2-pokracuje-v-budovani-5g-siete-naplno-k-pokrytiu-casti-bratislavy-pridalo-14-novych-lokalit-v-regionoch
[35] https://www.policytracker.com/5g-launches-in-indonesia-amid-spectrum-shortage/
[36] https://www.commsupdate.com/articles/2021/09/01/telekom-reaches-85-of-germans-with-5g/
[37] https://www.eir.ie/pressroom/eirs-5G-network-now-available-to-more-than-70-of-people-in-Ireland/
[38] https://firma.t-mobile.pl/dla-mediow/aktualnosci/informacja-prasowa/2021/09/blisko-230-nowych-stacji-5g-uruchomil-t-mobile-w-ciagu-ostatnich-dwoch-tygodni.html

- Nearly all EU countries have commercial 5G service
- 17 Member States are now involved in 5G cross border corridors. These stimulate the use of 5G in transport services.
- About 2/3rds of EU countries have assigned the 700 MHz and 3.6 GHz pioneer bands. 26 GHz band has been less widely deployed.

Figure 1: Overview of 5G developments



2.2.2 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:

- China has nearly 1 million 5G base stations: nine 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.

Figure 2: International 5G developments

	China	South Korea	Japan	USA	EU
5G Mode[6]	NSA/SA	NSA/SA	NSA	NSA	NSA/SA
Approximate number of 5G base stations	916,000	162,000	50,000	50,000	106,000
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	4224
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

3 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.

3.1 Market / industry

3.1.1 Update on status of commercial launches and frequency usage

At the end of October 2021, 5G commercial services were available in 25 of the EU-27 countries.[39] 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:

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.

[39] Unchanged compared to the previous report at the end of June 2021.

Country	Summary
	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.[40] 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[41]. *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** *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.[42]
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*

[40] https://www.rcrwireless.com/20210707/5g/drei-starts-5g-standalone-trials-headquarters-vienna https://www.speedtest.net/insights/blog/5g-austria-q1-q2-2021/
[41] The fastest 5G network in the country comes from Drei (in-24.com)
[42] Based on the Proximus 5G coverage map deployments meet EMF norms in Walloon and Flanders regions

Country	Summary
	Telenor launched in early June 2021 in the bigger cities in Bulgaria on the 3.6 GHz band.[43]
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 acquired 700 MHz and 3600 MHz bands.[44] Its 5G network currently covers 45 Croatian cities and a population of 1.7 million.[45]
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.[46] 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)[47], as well as O2, would have to lease the frequencies to support "Industry 4.0" services.[48]
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.[49]

[43] https://www.telenor.bg/en/news/telenor-bulgaria-received-permit-use-5g-frequencies
[44] https://5gobservatory.eu/5g-spectrum/national-5g-spectrum-assignment/#1533308480063-1f8df429-431f
[45] https://www.t.ht.hr/en/Press/press-releases/5625/Hrvatski-Telekom-s-the-first-in-Croatia-to-launch-5G-roaming.html
[46] https://cyprus-mail.com/2021/02/02/5g-understanding-the-full-value-chain-cyta-ceo/
[47] 5G - T-Mobile.cz
[48] https://www.ctu.eu/press-release-ctu-has-auctioned-frequencies-700-mhz-and-3400-3600-mhz-bands
[49] https://investindk.com/insights/danish-5g-launch-on-7-september-has-huge-commercial-potential

Country	Summary
	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* 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[50]. *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).[51] 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[52]* 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[53]* 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[54]. 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[55].

[50] 5G | Everything you need to know about 5G in Denmark | How to get 5G | Telia
[51] https://5gobservatory.eu/5g-spectrum/national-5g-spectrum-assignment/#1533308861084-6bfc1e56-ea0b
[52] 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
[53] Ericsson, Nokia ink new 5G deals with Finnish telco Elisa (rcrwireless.com)
[54] https://elisa.fi/5g/
[55] 5G network in Finland - Elisa

Country	Summary
	Telia - not specified, assumed to be NSA[56] 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* 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[57]. *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[58]. *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[59].
Germany	**Network operators offering 5G services: Deutsche Telekom, Vodafone, Telefonica** *Deutsche Telekom - not specified, assumed to be NSA*

[56] Collaboration announced with Ericsson for SA implementation.
Source:https://www.lightreading.com/5g/telia-picks-nokia-for-standalone-5g-core-in-six-markets/d/d-id/764771
[57] Bouygues switches on 5G, squeezing ahead of Orange - Telecoms.com
[58] Orange France to launch standalone 5G networks next year | LTEto5G
[59] Free mobile - 5G network

Country	Summary
	The operator plans to cover 90% of Germans by 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. Dynamic Spectrum Sharing is also being deployed. *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*[60] 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.

[60]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
Hungary	**Network operators offering 5G services: Magyar Telekom, Telenor, and Vodafone** *Magyar Telekom – not specified, assumed to be NSA* 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[61] *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.[62] *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[63]. *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*

[61] https://www.telekom.hu/lakossagi/english/customer-centre/coverage
[62] https://bbj.hu/business/tech/telco/telenor-to-have-several-hundred-5g-bases%C2%A0by-yearend
[63] 5G | 5G Ireland | Ireland's Best 5G Network - eir.ie

Country	Summary
	Italy has four operators with active 5G services. TIM recently announced a 5G cloud network and WindTre extended 5G dynamic spectrum sharing (DSS) to 93% of the country. Network/infrastructure sharing agreements have been announced between WINDTRE and Fastweb, and TIM and Vodafone.[64]
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.[65]
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.[66]
Malta	**Network operators offering 5G services: Melita** *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.[67]
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*

[64] https://www.speedtest.net/insights/blog/5g-italy-q2-2021/
[65] 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
[66] 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
[67] https://www.melita.com/help/mobile/5g/which-frequency-bands-does-5g-use/

Country	Summary
	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[68]. *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[69]. *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. *T-mobile - not specified, assumed to be NSA* The last operator to launch commercial service was T-Mobile using the 2100 MHz band.[70]
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.[71]
Slovakia	**Network operators offering 5G services: Slovak Telecom and Orange**

[68] T-Mobile's 5G, fast and stable internet | T-Mobile
[69] Polkomtel Sp. z o.o. | About the Company (plus.pl)
[70] https://www.commsupdate.com/articles/2020/06/09/t-mobile-poland-switches-on-5g/
[71] https://infocentru.ancom.ro/en/5g-commercial-services/#1610545667815-05466d39-5b8e

Country	Summary
	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.
Slovenia	**Network operators offering 5G services: Telekom Slovenije** *Telekom Slovenije - Not specified, assumed to be NSA* 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.[72]
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[73]. *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

[72] Telekom Slovenije's 5G Network Upgraded (total-slovenia-news.com)
[73] Telefonica's 5G network already reaches 80% of the Spanish population (rcrwireless.com)

Country	Summary
	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.[74]
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.[75] *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.[76] The operator expects to cover with its 5G network 99% of Sweden's population by 2023.

3.1.2 Coverage of commercial 5G

Although the initial focus of earlier EU initiatives such as the 5G Action Plan was on promoting and monitoring 5G deployment, in the EU Digital Decade initiative this has now shifted to 5G coverage as more Member States launch commercial services. Good 5G coverage will drive the

[74] https://www.rcrwireless.com/20210907/5g/masmovil-5g-network-reaches-553-towns-cities-across-spain
[75] https://www.lightreading.com/5g/telia-tele2-and-three-trumpet-swedish-5g-launches/d/d-id/759904
[76] https://www.rcrwireless.com/20201030/5g/telenor-launches-5g-stockholm-targets-nationwide-coverage-by-2023

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. The Commission defines populated areas as the “percentage of all places where households are located, including remote areas”.[77]

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 graph below.

It is important to note that at the time this graph was produced, only half of the Member States had begun their 5G network deployment. This has improved significantly, and as of October 2021, all but two Member States have launched commercial 5G services. Therefore, the current figure is likely to be higher.[78]

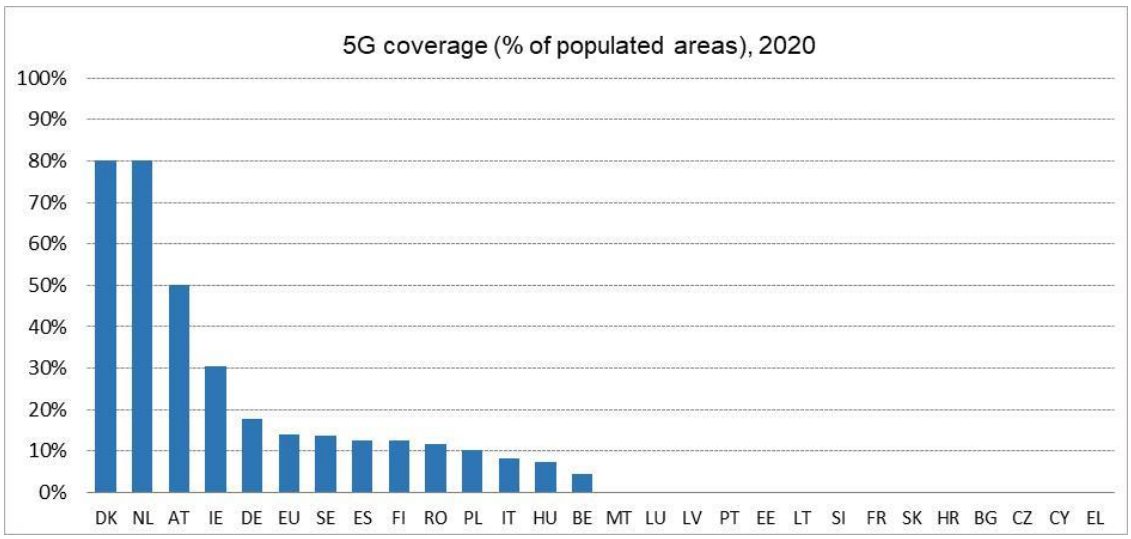


Figure 3: 5G coverage (% of populated areas) by Member State, 2020

Source: EC

[77] 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
[78] Updates compared to the baseline set by the estimates below are reported (where data is available) per Member State in **Error! Reference source not found.**

3.1.3 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.[79] 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 3.2.3 to see the full breakdown on a country-by-country basis.

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

Figure 4: International developments – overview

	China[80]	South Korea[81]	Japan[82]	USA[83]	EU
5G Mode[6]	NSA/SA	NSA/SA	NSA[84]	NSA	NSA/SA
Approximate number of 5G base stations	916,000	162,000	50,000	50,000	106,000
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	4224
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 39 GHz 47 GHz	700 MHz 3.6 GHz 26 GHz[85]

[80] Source: Global Times Jul 13, 2021: https://www.globaltimes.cn/page/202107/1228513.shtml
[81] Source: Korea Communications Agency https://en.yna.co.kr/view/AEN20210927001500320
[82] Source: 5G Observatory June 2021
[83] Source: International Business Strategies Inc. https://www.wsj.com/articles/u-s-vs-china-in-5g-the-battle-isnt-even-close-11604959200#refreshed
[84] KDDI due to launch SA at end of 2021: KDDI Presentation to 8th 5G Global Event, Oct 14-15 2021
[85] Note: Spectrum assignments differ by country. See spectrum assignment chart in 3.2.3 for full EU breakdown of assignments

Indicative 5G subscriber numbers[86]	**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)

3.1.4 5G Verticals (& trials)

3.1.4.1 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.

3.1.4.2 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

[86] 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

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

3.1.4.3 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[87] 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 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.[88]

In total 10 EU countries have proposed a local licensing model. Belgium, Sweden, and the Netherlands proposed a similar approach to Germany. In a slightly different

[87] https://www.gsma.com/spectrum/resources/mobile-networks-for-verticals/
[88] https://www.statista.com/statistics/295519/germany-share-of-economic-sectors-in-gross-domestic-product/

approach, France[89] has offered frequencies in the 2600 TDD MHz band to businesses. [90] 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. [91]

In Asia, the notion of 5G private networks has some traction. In Japan[92] a significant number of major companies have already acquired a spectrum licence.[93] 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. [94]

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 manufacturer John Deere has already announced plans to use its CBRS spectrum to install a private 5G network in its factories.[95]

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[96] 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.[97] Developments surrounding this band could have profound impacts on the development of 5G verticals.

[89] https://www.policytracker.com/air-france-gets-access-to-spectrum-for-business-lte-and-hopes-for-harmonised-5g-in-c-band/
[90] https://www.policytracker.com/air-france-gets-access-to-spectrum-for-business-lte-and-hopes-for-harmonised-5g-in-c-band/
[91] https://www.policytracker.com/air-france-gets-access-to-spectrum-for-business-lte-and-hopes-for-harmonised-5g-in-c-band/
[92] https://www.policytracker.com/japan-awards-its-first-commercial-licences-for-local-5g/
[93] https://www.policytracker.com/japan-awards-its-first-commercial-licences-for-local-5g/
[94] https://www.policytracker.com/south-korea-to-allocate-local-5g-spectrum-for-the-first-time/
[95] https://www.fiercewireless.com/private-wireless/john-deere-foresees-private-5g-at-its-factories-worldwide
[96] https://www.policytracker.com/ofcom-makes-3-8-4-2-ghz-available-for-private-networks/
[97] https://www.policytracker.com/3-8-4-2-ghz-gains-momentum-after-rspg-backing/

3.1.4.4 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.[98]

- **Belgium**: Proximus and the Port of Antwerp have announced a 6-month trial of a private 5G network.[99]

- **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.[100]

- **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.[101]

- **Spain**: Telefónica and APM Terminals have trialled 5G at the port of Barcelona. This test included connecting cranes, vehicles and people.[102]

[98] https://www.telekom.com/en/media/media-information/archive/port-of-hamburg-is-ready-for-5g-574536
[99] 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
[100] https://citymesh.com/en/news/port-of-zeebrugge-accelerates-innovation-by-investing-in-a-5g-network
[101] https://www.ericsson.com/en/cases/2017/5g-telia-tallink
[102] 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

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.[103]

- **Norway**: Ericsson, Telia and the Norwegian University of Science and Technology have carried out a demonstration of a 5G autonomous ferry.[104]

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 (3.1.5), including country by country examples of private networks and their associated vertical trials.

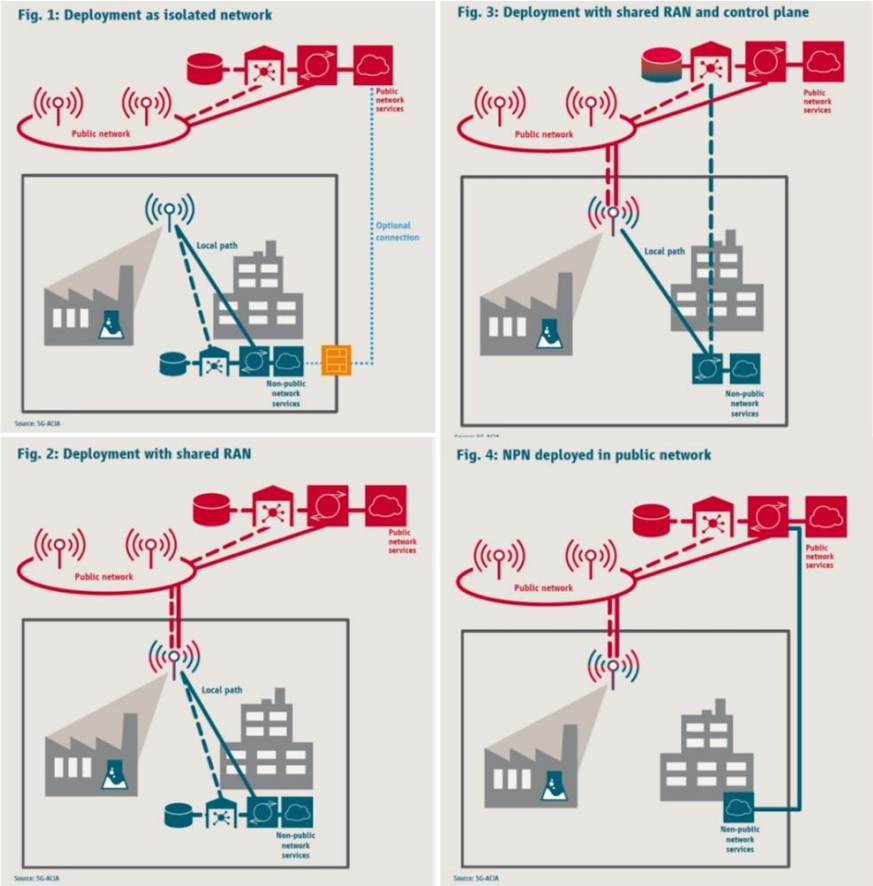
There are, however, some verticals which will run on public networks. An example of this is both Deutsche Telekom[105] and Vodafone[106] Germany’s recent announcement of 5G plans for the BMW iX car. This integration allows drivers to use 5G connectivity in their cars.

3.1.5 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).

[103] 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/
[104] https://www.teliacompany.com/en/news/news-articles/2019/telia-tests-5g-powered-autonomous-vessels/
[105] 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
[106] 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

Figure 5: 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
- Identifies which companies are deploying private networks
- Identifies the sectors in which private 5G networks are being deployed
- The spectrum band being used where information is available

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[107]. 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	
Belgium	Port of Antwerp	Proximus		As introduced in 3.1.4.4, 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

[107] 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.
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
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.

Country	Company /Entity	Operator	Equipment vendor	Overview
				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)
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 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

Country	Company /Entity	Operator	Equipment vendor	Overview
				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 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

Country	Company /Entity	Operator	Equipment vendor	Overview
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
Greece	Calpak[108] (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[109]	Vodafone	Ericsson	Support for manufacturing in the factory to improve efficiency and remove lots of cabling
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

[108] https://enterpriseiotinsights.com/20210215/channels/news/cosmote-ericsson-ptc-claim-first-lte-campus-network-in-greece
[109] https://bbj.hu/business/tech/telco/hungarys-1st-industrial-5g-private-network-goes-live-at-foxconns%C2%A0factory

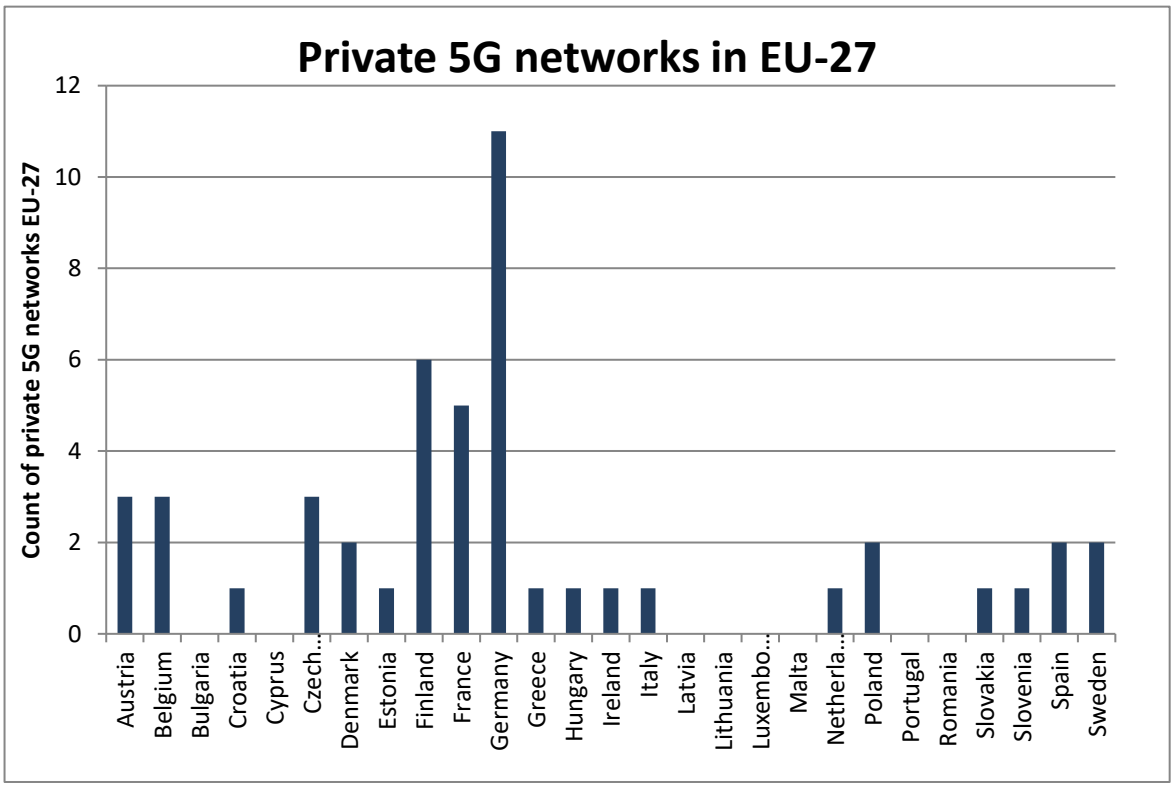
Country	Company /Entity	Operator	Equipment vendor	Overview
				production lines and mobile robots, as well as augmented reality (AR) and virtual reality (VR) displays
Italy	Exor International	TIM	Athonet	Private 5G network deployed for factory automation and new digital services.
Netherlands	Shell, ABB 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)-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
Slovakia	CEIT (R&D centre)[110]	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

[110] https://www.telecompaper.com/news/slovak-telekom-launches-5g-network-in-zilina-bratislava--1365300

Country	Company /Entity	Operator	Equipment vendor	Overview
Spain	BASF	Masmovil	Cellnex, Nokia, Lenovo	November 2020: German chemicals company BASF and Spanish telecommunications infrastructure and services operator 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

A summary of the number of private 5G networks deployed across the EU-27 countries is shown in the plot below.

Figure 6: 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 2: 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 highdefinition 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

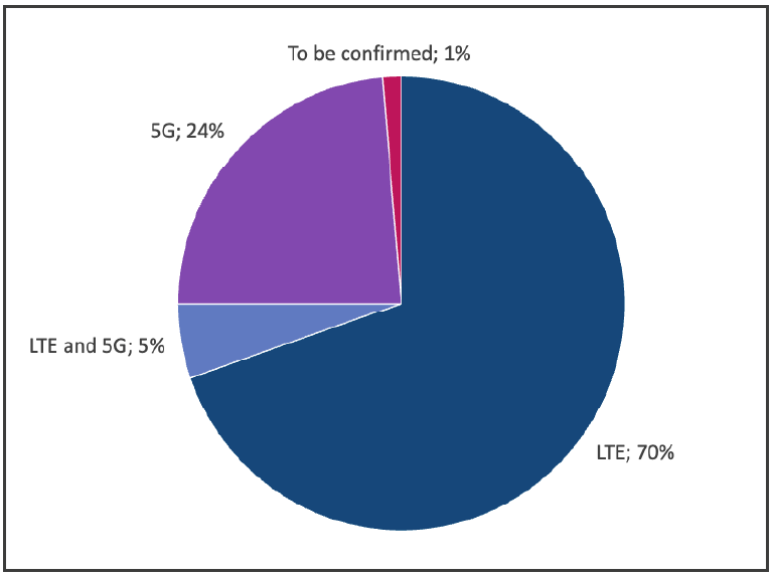
Country	Company/Entity	Operator	Equipment Vendor	Comments
				exact spot where they are required based on communication with production line equipment.
Russia	EVRAZ	Mobile TeleSystems PJSC (MTS)	Ericsson	Ericsson and Mobile TeleSystems PJSC (MTS) announced plans to jointly deploy a commercial LTE/5G-ready 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.
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. 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	Vodafone	Ericsson	Centrica Storage Limited, the gas storage and processing unit of UK gas and electricity supplier Centrica.

Country	Company/Entity	Operator	Equipment Vendor	Comments
	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 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.

Country	Company/Entity	Operator	Equipment Vendor	Comments
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.
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.

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 September 2021[111] 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 528 private cellular network deployments worldwide, the GSA indicate that around 29% (153 deployments) use 5G.

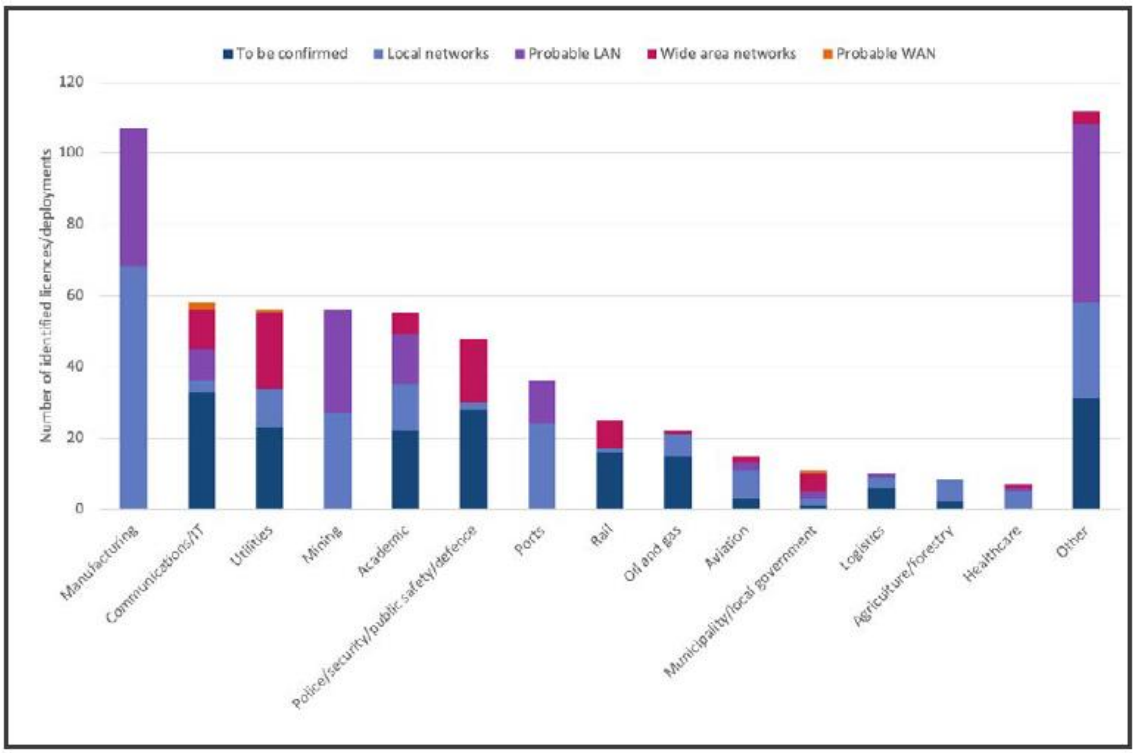
Figure 7: Proportion of private mobile network deployments using 5G



The GSA also highlights in its September report that the main industries deploying local area networks include manufacturing, mining and ports with other sectors such as aviation and healthcare also deploying networks. In addition, the GSA includes the leading sectors deploying wide area private cellular networks and the sectors include utilities, police/public safety, communications/IT and rail. 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 626 organisations.

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

Figure 8: Number of identified deployments across industrial sectors



3.1.6 Vendors: Open RAN, multivendor deployments

3.1.6.1 Overview

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

- Opening of interfaces to enable multi-vendor implementations and interoperability between different vendor gears (X2, Xn, Open fronthaul interface)
- Softwarisation 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

The objectives of Open RAN are i) to reduce cost of implementation and OPEX; ii) to provide more flexibility for introduction of innovative components; iii) to facilitate multivendor implementations or replacement

There are two 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[112]". 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.

3.1.6.2 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 and has developed the OpenRAN reference architecture (shown below) which demonstrates how the key components for both hardware and software fit together but also shows where and between which components the different interfaces (backhaul, middlehaul and fronthaul) are placed within the network architecture.

Figure 9: OpenRAN reference architecture. Source: Telecominfraproject.com

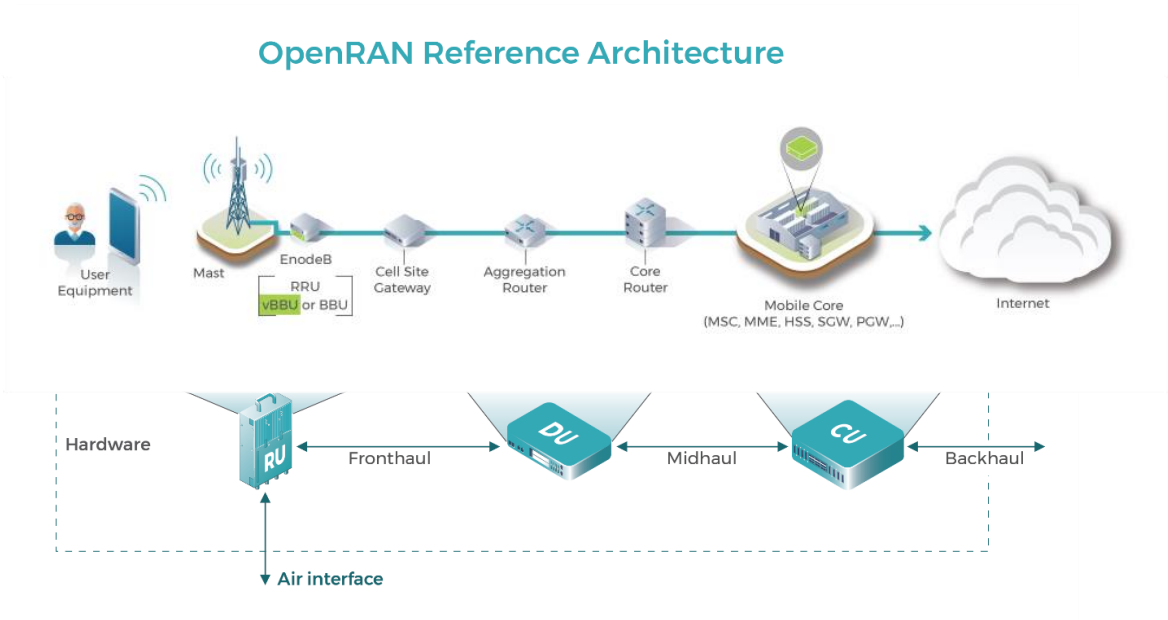


Figure 10: OpenRAN end to end architecture: Telecominfraproject.com

More specifically, the key Open RAN tenets include:

[112] 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/

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. Supply Chain Diversity

3.1.6.3 Open-RAN Alliance (O-RAN)

The Open RAN Alliance was founded by operators (DT, Orange, CMCC, AT&T, Barti) 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*[113]”. 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.

[113] www.o-ran.org

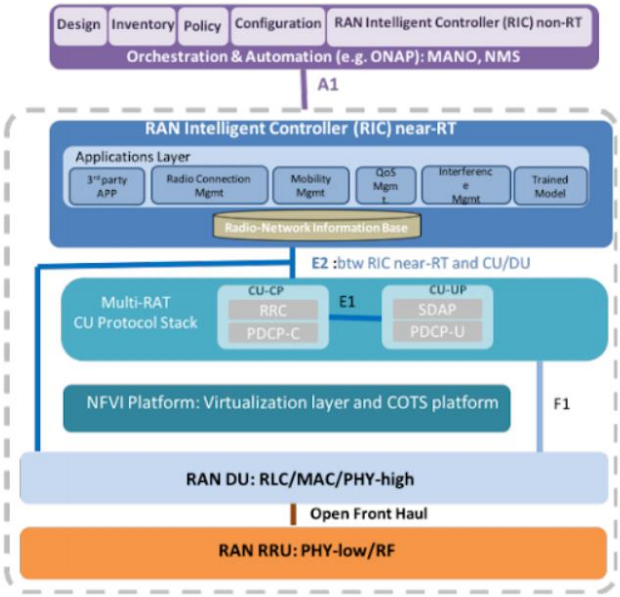


Figure 11: O-RAN Alliance reference architecture. Source: O-RAN Alliance

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.

3.1.6.4 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 3: Open RAN MoU implementation phases and releases

	Phase	Time Horizon
P0	Creation of the “Technical Priority Document”	Completed[114]
P1	Readiness for Pre-Commercial PoC (related to release R1)	From 2021

[114] Technical Priority Document, Telefónica, https://www.telefonica.com/documents/737979/146026852/Open-RAN-Technical-Priorities-Executive-Summary.pdf/cdbf0310-4cfe-5c2f-2dfb-c68b8c8a8186

	Phase	Time Horizon
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

3.1.6.5 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
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				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[115] 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 12: OpenRAN deployments globally. Source: Deloitte

At this stage, most of the Open RAN deployments are pilots intended to validate the technology and most advanced deployments, primarily targeting low-density rural zones, in view of being compatible with the capabilities of the technology.

Out of 176 commercial 5G networks in the world, two are fully applying Open RAN principles (though with specific specifications): Dish and Rakuten.

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

3.1.6.6 Next steps for Open RAN

It is anticipated that Open RAN deployments will start to increase globally as the technology and capability matures. One particular 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[116].

In Europe, the major 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. It is expected therefore to see growth of adoption in mobile networks across the EU-27 over the next five years.

3.1.7 EMF developments related to 5G policy goals

5G cannot be deployed unless 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.[117] However, 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[118]. A European Council Recommendation (1999/519/EC) [119] set EMF limits based on the ICNIRP guidelines.

The 2018 Electronic Communications Code[120] says protecting public health is "imperative" and urges Member States to take a consistent approach having "particular regard" to 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

[116] https://www.delloro.com/news/open-ran-market-expected-to-approach-10-b/
[117] See *Health impact of 5G* (July 2021): a study for the European Parliament

[118] See ICNIRP GUIDELINES FOR LIMITING EXPOSURE TO ELECTROMAGNETIC FIELDS (100 kHz TO 300 GHz) (1998 then updated in 2020) p484 and 492
[119] See https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999H0519&from=EN
[120] 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)

Organisation 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”[121].

3.1.7.1 Inconsistency in EMF limits

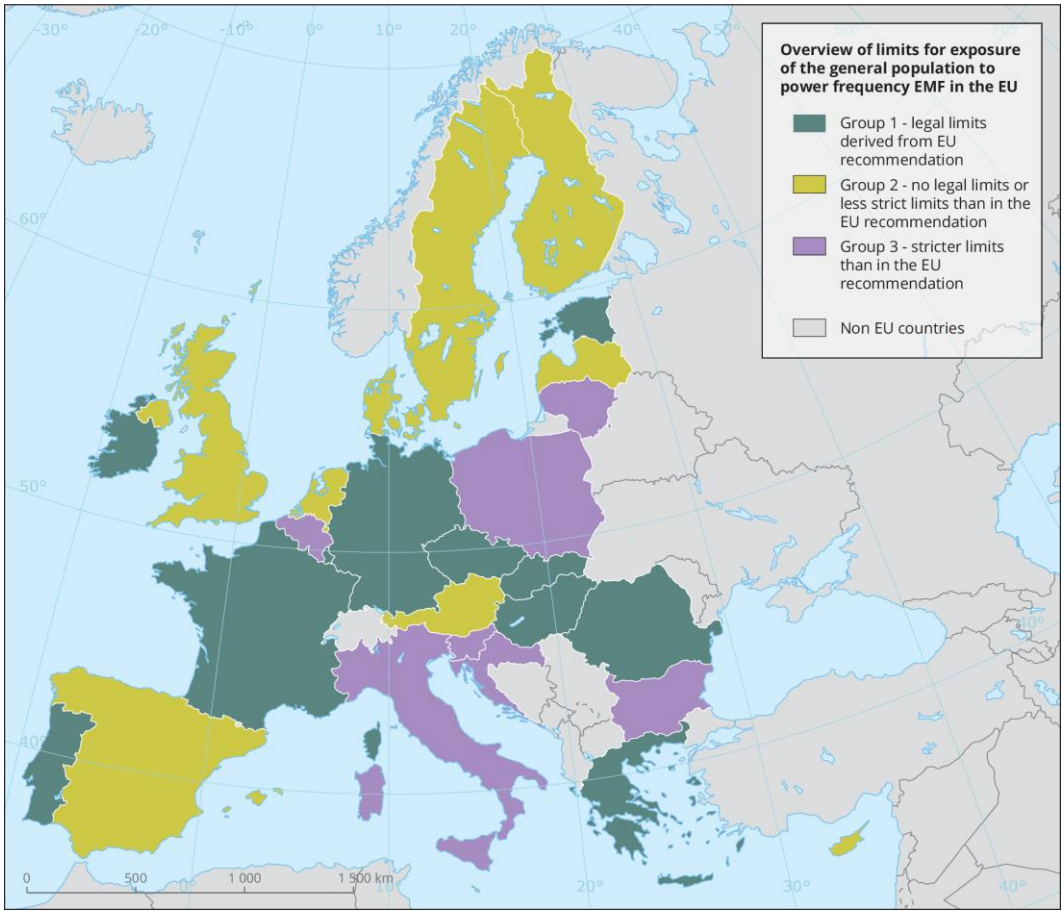
Two pieces of research have highlighted this inconsistency in approaches to EMF limits. The first was carried out by the National Institute for Public Health in the Netherlands in 2018[122]. It said there were three approaches to EMF in EU countries:

1. **Group 1:** the EU recommendation has been transposed in binding national legislation or national policy.
2. **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:

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

Figure 13: 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 4: 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

3.1.7.2 New EU rules on small cells

In June 2020 the European Commission adopted new rules[123] 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 isotropical 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.[124]

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"[125], which may offer space for the continued application of stricter EMF limits.

[123] See https://digital-strategy.ec.europa.eu/en/news/commission-adopts-implementing-regulation-pave-way-high-capacity-5g-network-infrastructure
[124] See Implementing Regulation points 5, 6 and 8
[125] 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.[126]

3.2 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.

3.2.1 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[127] 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[128], 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.[129] 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

[126] Ibid Article 4
[127] An overview of these strategies can be found in the annex of previous quarterly report versions
[128] https://digital-strategy.ec.europa.eu/en/library/connectivity-toolbox-member-states-develop-and-share-roadmaps-toolbox-implementation
[129] Proposal for a Decision establishing the 2030 Policy Programme "Path to the Digital Decade" | Shaping Europe's digital future (europa.eu)

    - 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
    - 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

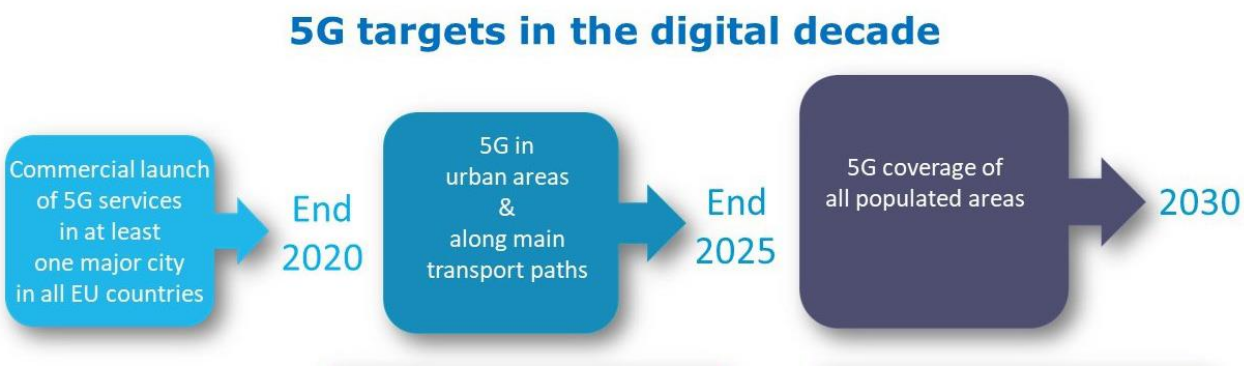
Following the entry into force of the Digital Decade Policy Programme:

- 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.[130]

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

3.2.2 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

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

Corridors for CAM. This will unlock this ecosystem in Europe following a Strategic Deployment Agenda (SDA) developed by a broad range of stakeholders.[131]

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.[132] 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).[133] The table below presents the situation regarding the on-going initiatives.

Table 5: 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

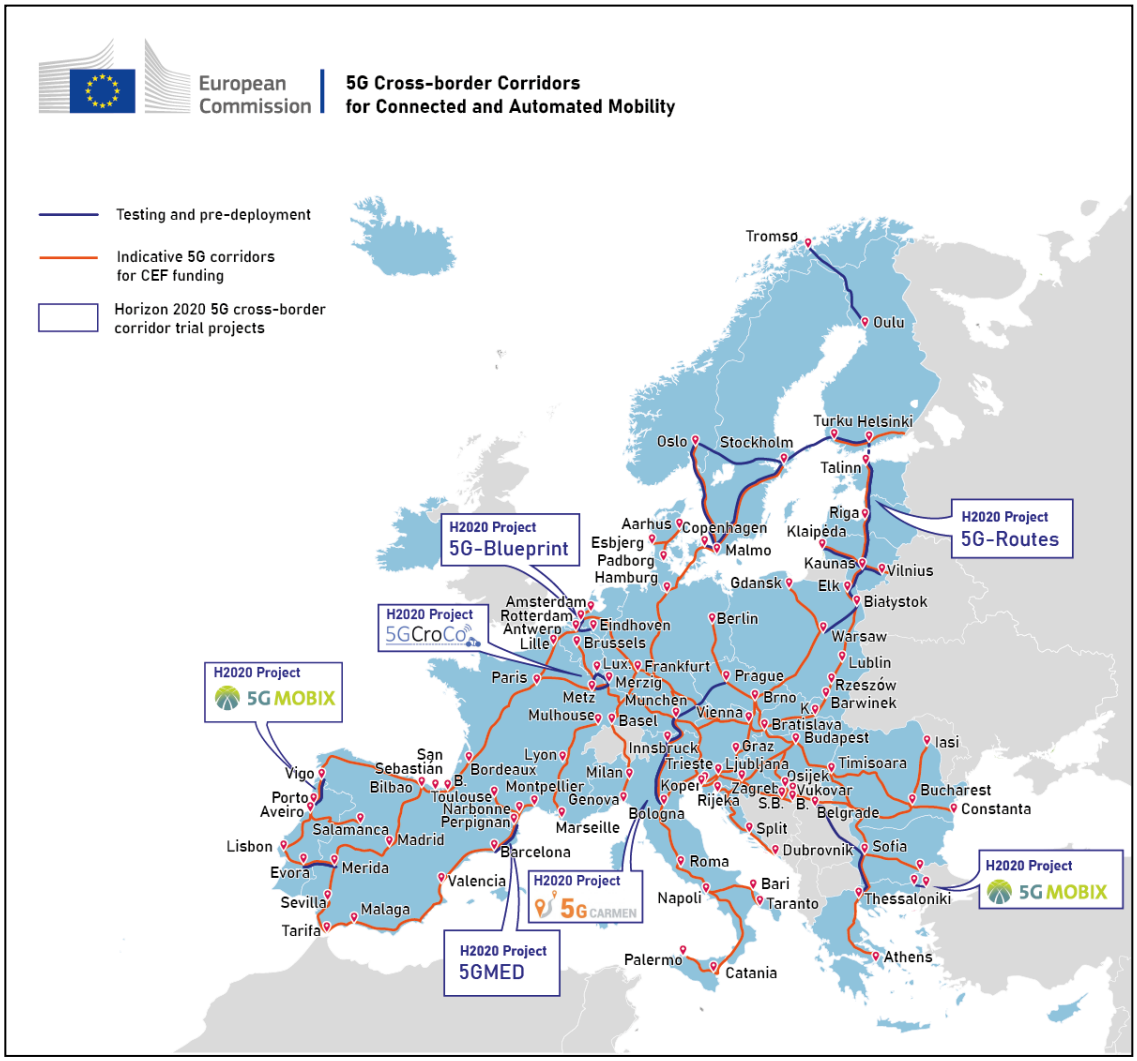
[131] https://digital-strategy.ec.europa.eu/en/policies/5g-digital-decade
[132] https://digital-strategy.ec.europa.eu/en/policies/cross-border-corridors
[133] https://5g-ppp.eu/5g-blueprint/

5G Corridors	Political Commitment	H2020 projects (calls ICT-18 and ICT-53)
Antwerpen-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 14: 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[134], the three projects cover three 5G cross-border corridors: Metz-Merzig-Luxembourg (5GCroCo[135]), Porto-Vigo between Spain and

[134] https://www.5g-mobix.com/newsandevents/pressreleases/working-together-on-5g-three-cross-border-and-corridor-projects-launched-at-ict2018
[135] https://5gcroco.eu/

Portugal (5G-Mobix[136]), and Bologna-Munich via the Brenner Path (5G-CARMEN[137]). 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)[138] and the Resilience and Recovery Facility (RRF)[139]. The first CEF calls are expected to be launched by October-November 2021 (inception studies and early wave of deployment work).

3.2.3 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, 53.1% of pioneer bands have been assigned in the EU.

3.2.3.1 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.

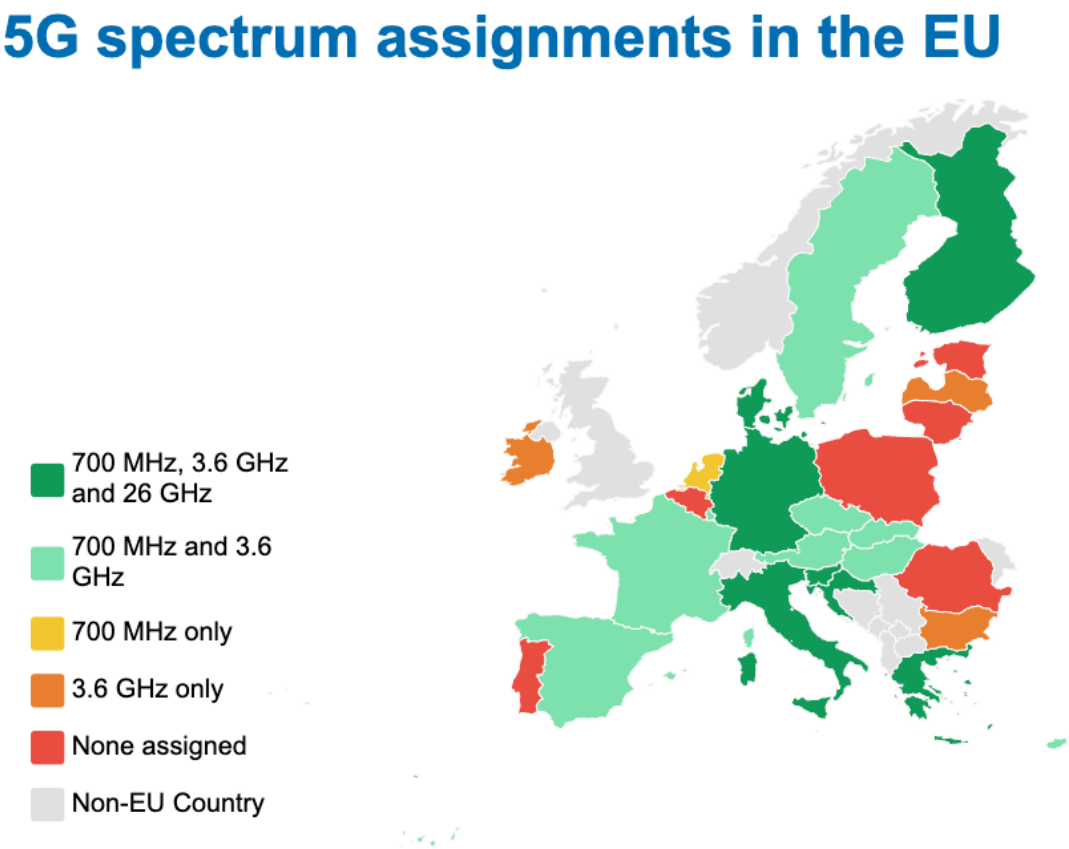
The 5G pioneer bands identified at EU level are as follows:

- 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.

[136] https://www.5g-mobix.com/
[137] https://5gcarmen.eu/
[138] https://digital-strategy.ec.europa.eu/en/activities/connecting-europe-facility
[139] https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en

3.2.3.2 EU Trends



Source: Regulator announcements and consortium’s own research

3.2.3.3 Pioneer bands assigned in the EU

Amongst Member States, the 3.6 GHz band has been most widely assigned. Nineteen out of 27 Member States have assigned this band. The second most popular band is the 700 MHz band, which has been assigned in 17 out of 27 Member States. The least popular band is the 26 GHz band, which has only been assigned in seven Member States. Finally, seven Member States have failed to assign any of the pioneer bands.

Notably, there have been differences in how the pioneer bands are assigned, particularly in the 26 GHz band.

Table 6: Pioneer bands assigned in the EU

Country	700 MHz	3.6 GHz	26 GHz
Austria	Yes	Yes	No
Belgium	No	No[140]	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[141]
Greece	Yes	Yes	Yes
Hungary	Yes	Yes	No
Ireland	No[142]	Yes	No
Italy	Yes[143]	Yes	Yes
Latvia	No	Yes	No

140 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

141 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

142 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/

[143]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
Lithuania	No	No	No
Luxembourg	Yes	Yes	No
Malta	No	No	No
Netherlands	Yes	No	No
Poland	No	No	No
Portugal	No	No	No
Romania	No	No[144]	No
Slovakia	Yes	Yes	No
Slovenia	Yes	Yes	Yes
Spain	Yes	Yes	No
Sweden	Yes	Yes	No

In Germany, for example, a part of the band is made available for local licensing. 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.

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.[145]

Overall, 52.7% of pioneer bands have been assigned, with the following breakdown per band:

- 700 MHz: 61.1% % assigned and 38.9% not assigned.

144 Note: Auction in progress (as of 18/08/2021), https://www.ancom.ro/ancom-lanseaza-licitatia-pentru-noi-licen539e-de-spectru-destinat-serviciilor-de-comunica539ii-mobile_6378

145 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/

- 3.6 GHz:: 70.9% assigned, 29.1% not assigned.
- 26 GHz: 25.9% assigned, 74.1% not assigned

3.2.3.4 International trends

The three pioneer bands harmonised by the EU Commission roughly fit into the three categories of 5G bands 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, categorising the spectrum in this way allows for an easier international comparison on the state of 5G spectrum harmonisation and assignment.

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

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.[146]

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.[147] 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.

3.2.4 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.[148]

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.[149] These risks can be largely categorised into four categories. These include:

- Local or global 5G network disruption (Availability);
- Spying of 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).

146 https://www.mobileworldlive.com/asia/asia-news/korea-auction-attracts-limited-interest-700mhz-goes-unsold
147 https://developingtelecoms.com/telecom-technology/enterprise-ecosystems/11886-china-mobile-and-cbn-settle-700mhz-5g-plan.html
148 https://digital-strategy.ec.europa.eu/en/library/report-member-states-progress-implementing-eu-toolbox-5g-cybersecurity
149 https://ec.europa.eu/commission/presscorner/detail/en/IP_19_6049

The Toolbox found a total of eight strategic measures that address these risks. Below you will find a summary of these measures as well as an illustrative example from a Member State (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.[150] 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;

150 https://www.riigikogu.ee/en/sitting-reviews/riigikogu-amended-electronic-communications-act/

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

- 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.

3.2.5 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[151] 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)[152] 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.[153]

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.[154]

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).[155] 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.[156]

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.[157] 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%

[151] https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf
[152] https://etno.eu/
[153] https://etno.eu/downloads/positionpapers/etno%20position%20paper_2030%20climate%20targets%20ec%20public%20consultation.pdf
[154] https://smarter2030.gesi.org/
[155] https://www.ericsson.com/en/blog/3/2021/1/achieving-sustainability-with-energy-efficiency-in-5g-networks
[156] https://www.edie.net/news/6/Vodafone-plans-1-500-energy-efficient-5G-radios-after-trials-halve-energy-consumption/
[157] 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

reduction in global CO2 emissions in 2019, fulfilling in advance the company's target for 2025[158]. Vodafone is committed to net zero for our own operations by 2030, and for our full carbon footprint by 2040.[159] 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[160] 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.[161] Deutsche Telekom also tracks its energy efficiency KPI overtime and linked improvements to the 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.[162]

- **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. [163] Turkcell has made a commitment to exclusively rely on renewable sources by 2030.[164]. Telecom Italia (TIM) will cover around 20% of the company’s energy consumption through renewable sources through an agreement with ERG wind farms.[165] By mid- 2021, Vodafone’s European network will be powered by 100% renewable electricity.[166]

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

Table 7: overview of targets and commitments by operators:

[158] https://www.telefonica.com/en/web/press-office/-/telefonica-brings-its-zero-emissions-target-forward-to-2030
[159] https://www.vodafone.com/sustainable-business/our-purpose-pillars/planet/net-zero-by-2040
[160]https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=60621137&file=300621-Going-Green-efficiency-mobile.pdf
[161] https://www.vodafone.com/news/press-release/100percent-renewables
[162]https://www.telekom.com/en/media/media-information/archive/deutsche-telekom-tightens-its-climate-targets-623582
[163] https://www.telekom.com/en/media/media-information/archive/deutsche-telekom-tightens-its-climate-targets-623582
[164] https://www.turkcell.com.tr/en/aboutus/corporate-social-responsibility/sustainability
[165] https://www.gruppotim.it/en/press-archive/corporate/2021/CS-TIM-ERG-en.html
[166] https://www.vodafone.com/news/press-release/vodafone-commits-to-net-zero-carbon-emissions-by-2040

Mobile network operator	Science-based targets[167]	Carbon Neutral Target Year[168]	Net Zero Target Year[169]
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	
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	

[167] Science-based targets source: https://sciencebasedtargets.org/companies-taking-action/
[168] Carbon neutral target refers to reducing and offsetting carbon emissions from own operations (all Scope 1 and 2 emissions)
[169] Net zero refers to the criteria used by the UN Race To Zero campaign

Mobile network operator	Science-based targets[167]	Carbon Neutral Target Year[168]	Net Zero Target Year[169]
Telefónica	1.5°C		2025/2040[170]
Telenor Group	Committed Feb 2020	2030[171]	
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 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.[172]

[170] 2025 in its four main markets. 2040 including all operations and value chain.
[171] Nordic operations
[172] https://www.gsma.com/betterfuture/enablement-effect

3.3 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.[173] 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[174] 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[175] 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[176] (the centrepiece of NextGenerationEU[177]) 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[178] 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

[173] https://digital-strategy.ec.europa.eu/en/policies/5g
[174] Europe’s Digital Decade: digital targets for 2030 | European Commission (europa.eu)
[175] McKinsey, Shaping the digital transformation in Europe, September 2020
[176] Recovery and Resilience Facility | European Commission (europa.eu)
[177] Recovery plan for Europe | European Commission (europa.eu)
[178] Recovery and Resilience Facility | European Commission (europa.eu)

3.3.1 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)**[179]: 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 transition.

- **Structural and investment Funds (ESIF)** [180]: 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[181], 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**[182]: 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, 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:

[179] Recovery and Resilience Facility | European Commission (europa.eu)
[180] 2021-2027 - EU allocations available for programming | Data | European Structural and Investment Funds (europa.eu)
[181] European Regional Development Fund - Regional Policy - European Commission (europa.eu)
[182] Connecting Europe Facility | Shaping Europe's digital future (europa.eu)

- 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.[183]
- 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**[184]: 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)**[185]: 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.

- **Horizon Europe**[186] (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

[183] Source: https://digital-strategy.ec.europa.eu/en/activities/connecting-europe-facility
[184] Space for 5G | ESA TIA
[185] Smart Networks and Services Joint Undertaking | Shaping Europe's digital future (europa.eu)
[186] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

the climate change, helping to achieve the United Nations Sustainable Developments Goals and to boost the EU’s competitiveness and growth.

- **InvestEU**[187] (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[188] 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

[187] InvestEU | InvestEU (europa.eu)
[188] InvestEU Fund | InvestEU (europa.eu)

3.3.1.1 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 8: Selection of EU-27 relevant R&I initiatives

Country	Initiative/project	Short description
Austria	Gigabit Triple A[189]	"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[190]	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[191]	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.

[189] Gigabit Triple A: Awareness.Applications.Austria | FFG
[190] https://genius.aero
[191] Digital Testbed Framework - e-Estonia

Country	Initiative/project	Short description
Finland	5GTNF[192]	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[193]	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[194]	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)

[192] Home - 5GTNF
[193] 5g-force
[194] 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[195]	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[196]	Sat5G project will bring satellite communications into 5G by defining optimal satellite-based backhaul and traffic offloading solutions.
Finland	5G-RANGE[197]	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”[198]	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

[195] Dedicat6G – Dynamic coverage Extension and Distributed Intelligence for human Centric Applications
[196] SaT5G Project - Sat 5G (sat5g-project.eu)
[197] Remote area Access Network for the 5th GEneration – Remote area Access Network for the 5th GEneration (5g-range.eu)
[198] 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.[199]
France	Acceleration strategy on 5G and future telecommunications network technologies[200]	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.

[199] 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

[200] 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”[201]	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[202]	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.

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

Country	Initiative/project	Short description
Italy	“Italia 5G” Plan[203]	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[204]	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.

[203] Strategia BUL.docx (mise.gov.it)
[204] 5G-EMIT | Luxembourg Institute of Science and Technology (list.lu)

Country	Initiative/project	Short description
Luxembourg	Call for projects[205]	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.
Netherlands	5Groningen[206]	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[207]	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.

[205] 5G - government.lu (gouvernement.lu)
[206] 5Groningen gaat nog zeker twee jaar door › 5Groningen
[207] Home | Arctic 5G Test Network

4 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	By 2021 there had been commercial 5G launches in all EU countries, with two exceptions: Lithuania and Portugal. All deployments to date cover major cities and urban areas.	Countries with no commercial service launched to date i.e. Lithuania and Portugal.	Investigating the root cause of the issue to launch commercial service is a first step to potentially solve it. In the case of Portugal, the multi-band spectrum auction took an exceptionally long time and only ended on 28 October after 201 days of bidding.[208] This was after ANACOM had taken measures to speed up the process such as increasing minimum bidding increments and number of daily bidding rounds. [209] For Lithuania, the auction for pioneer bands is yet to start.[210] The regulator RRT expects to announce the frequency auction very soon (after signing a memorandum among public sector institutions and mobile operators on 5G development)[211]. One of the biggest obstacles pointed out by the regulator have been the negotiations with bordering countries (e.g. Russia) on the release of the priority 3.5 GHz frequency band. RRT therefore expects commercial launch is in Vilnius by 2022[212] and trials have already been carried out by some operators within existing spectrum holdings.[213]
Uninterrupted 5G wireless broadband coverage for all	Based on data collected by the Commission in 2020, the baseline for	As a result of research performed at Member State level, the study team	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

[208] https://www.anacom.pt/render.jsp?categoryId=416583
[209] https://www.policytracker.com/blog/the-agony-continues-in-portugals-record-breaking-auction/ and https://www.policytracker.com/portugal-raises-over-e560-million-in-longest-ever-auction
[210] https://www.rrt.lt/en/public-and-private-sectors-agreed-on-actions-regarding-5g-connection-in-lithuania/
[211] https://www.rrt.lt/en/public-and-private-sectors-agreed-on-actions-regarding-5g-connection-in-lithuania/
[212] https://kaunas.kasvyksta.lt/2021/10/12/mokslas-ir-it/5g-rysys-lietuvoje-bus-diegiamas-3-etapais-pirmasis-aukcionas-po-dvieju-savaiciu/
[213] https://www.telia.lt/pranesimai-spaudai/telia-is-launching-5g-network-in-lithuania

urban areas and major roads and railways.	population coverage in the EU is estimated at 14%.[214]	identified a lack of consistent reporting at MS level (for example coverage of major roads and railways is only reported in Finland).	indicators, defined by the Commission in the DESI on a yearly basis.[215, 216]
“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 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.	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.
Authorising 5G spectrum bands	The 3.6 GHz band has been most widely assigned. Nineteen out of 27 Member States have assigned this band. The second most popular band is	Lack of demand for the 26Ghz band. Further development of harmonised approach to	Referring specifically to the 26GHz band, there have been differences in the way the band has been made available suggesting there is no

[214] 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
[215] Source: Proposal for a Decision establishing the 2030 Policy Programme “Path to the Digital Decade”
[216] For more information regarding 5G targets in the digital decade see: https://digital-strategy.ec.europa.eu/en/policies/5g-digital-decade

	the 700 MHz band, which has been assigned in 17 out of 27 Member States. The least popular band is the 26 GHz band, which has only been assigned in seven Member States. Finally, seven 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	spectrum sharing for local networks	“universal formula”. Most approaches however take into account the use of the band for industrial applications and 5G verticals.[217]
Promoting pan-European multi-stakeholder trials[218]/ 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.[219]	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.

[217] 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.
[218] 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.
[219] CZ, ES, IT, LV, EL, LT plans.
Source: Commission Staff Working Document

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.[220]	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).

[220] https://digital-strategy.ec.europa.eu/en/library/report-member-states-progress-implementing-eu-toolbox-5g-cybersecurity

5 Conclusions and next steps

This thirteenth quarterly report of the European 5G Observatory for the third 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 next steps and updates to be presented in the following publication include:

- **Forecasting activity to anticipate EU 27 progress towards the achievement of EU Policy (5G AP and Digital Decade Targets):** key quantitative information collected throughout this report and upcoming publications (e.g. base stations, coverage) as well as trends and developments identified, will constitute the basis for the future model’s estimates. For instance, the Commission Staff Working Document accompanying the 2030 Policy Programme “Path to the Digital Decade” uses the historical evolution of 4G coverage (2011-2020) to project 5G coverage taking into account completed and planned spectrum assignments.[221]

- I**nterviews**: linked to the activity above (i.e. to develop a forecasting model for key indicators monitoring progress), collected historical data and assumptions, will be fine-tuned and verified against expert opinion. Once the scenarios and state of the art (base case scenario) are defined, the study team will start an iterative process with industry experts to validate working assumptions as well as findings.

- **Workshop**: the 3rd European 5G Observatory Stakeholder Workshop organised by the study team on November 18th will be an 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.

- Finally, a full strategic discussion including roadmap will be included in the final report.

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

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).[222] Individual operator announcements: A1 telekom network at the end of January 2020 launched its commercial 5G services covering 350 locations across 129 municipalities. [223]Magenta Telekom ended 2020 with 1,200 5G sites nationwide[224]	
	- Number of base stations deployed (progress of deployments	1,252[225]	
	- Network performance: speed	200 Mbit/s[226]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	65.8%[227]	
-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)[228]	

[222] Drei lists 78 cities, while Magenta mentions 1,400 locations across the country
[223] https://www.rcrwireless.com/20210104/5g/magenta-telekom-5g-network-reaches-1200-sites-across-austria
[224]https://www.rcrwireless.com/20210216/carriers/austria-remains-a-5g-pioneer-even-as-infrastructure-fees-threaten-rollout
[225] Source: EC
[226]Source : RTR
[227]Source DESI
[228] Source : DESI (2020 data)
Magenta Telekom said it had reached around 40% of households and businesses in Austria in 2020. Source: https://www.rcrwireless.com/20210125/5g/magenta-telekom-to-cover-half-of-austrian-households-with-5g-this-year

	- 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**[229]	
	- 5G verticals (trials &) initiatives	None identified	
Other (indirectly relevant) targets[230]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	53%[231]	

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[232]	
	- Network performance: speed	70 Mbps[233]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	3.3%[234]	

[229] Regional licences in 3400-3800 MHz
[230] 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.
[231] €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
[232] Source: EC
[233] Overall mobile data speed 08/21; Source : Ookla
[234]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	4.43% 0% (rural)[235]	
	- 5G corridors	Antwerpen-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[236]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	27%[237]	

5.1.3 Bulgaria

Target	Indicator(s)	Performance	On Track
-Commercial launch of 5G services at least in	- Urban areas covered (progress of deployments)	circa 190 locations (Sept 2021 overview based on Ookla).	

[235]Source : DESI (2020 data)
[236] 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.
[237] € 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

one major city in all EU countries (by 2020)	- Number of base stations deployed (progress of deployments	257[238]	
	- Network performance: speed	226.6 Mbps[239]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[240]	
-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)[241]	
	- 5G corridors	"Thessaloniki, Sofia-Belgrade EL-BG-RS"[242]	
-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	

[238] Source: EC
[239] 5G speeds 09/2021; Source : Ookla
[240]Source: DESI (5G readiness ; 2020 data)
[241]Source: DESI (2020 data)
[242]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[243]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[244]	

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[245]	
	- Number of base stations deployed (progress of deployments	449[246]	
	- Network performance: speed	78 Mbps[247]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[248]	
-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)[249]	
	- 5G corridors	No agreement/project identified	

[243] 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.
[244] Source: https://www.nextgeneration.bg/upload/36/Bulgaria_Recovery_and_Resilience_Plan_ENG.pdf
[245] Source : Hrvatksi Telecom
[246] Source: EC
[247] Overall mobile data speed 08/21; Source : Ookla
[248]Source: DESI (5G readiness)
[249]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**[250]	
	- 5G verticals (trials &) initiatives	0 trials identified	
Other (indirectly relevant) targets[251]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	20%[252]	

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[253]	
	- Network performance: speed	136.18 Mbps[254]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	66.7%[255]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[250] Regional licences in 3410-3800 MHz
[251] 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.
[252] € 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
[253] Source: EC
[254] Overall mobile data speed 08/21; Source : Ookla
[255]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)[256]	
	- 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[257]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	23%[258]	

5.1.6 Czechia

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 550 locations (Sept 2021 overview based on Ookla).[259]	
	- Number of base stations deployed (progress of deployments	1,073[260]	

[256]Source : DESI (2020 data); Cyta planned initial population coverage of 70%
[257] 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.
[258]€ 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.
[259] More than 130 cities and smaller municipalities covered by Vodafone and 60 cities by O2.
[260] Source: EC

	- Network performance: speed	58.46 Mbps[261]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	66.7%[262]	
-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)[263]	
	- 5G corridors	Czech-Bavarian 5G corridor[264]	
-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[265]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[266]	

[261] Overall mobile data speed 08/21; Source : Ookla
[262]Source: DESI (5G readiness)
[263]Source : DESI (2020 data); T-mobile reports population coverage of 10.4%, Vodafone over 20%
[264]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/
[265] 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.
[266]€ 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

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).[267]	
	- Number of base stations deployed (progress of deployments	3,146[268]	
	- Network performance: speed	103.35Mbps [269]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	33.3%[270]	
-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)[271]	
	- 5G corridors	Nordic Way2 NO-SE-FI-DK [272]	
-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	**Proposed**[273]	

[267] Initial launch by TDC covered larger urban areas such as Copenhagen, Aarhus and Odense, with planned nationwide (80%) population coverage by September 2020. .
[268] Source: EC
[269] Overall mobile data speed 08/21; Source : Ookla
[270]Source: DESI (5G readiness)
[271]Source : DESI (2020 data);
[272]https://www.nordicway.net/
[273] 3740–3800 MHz under investigation

products, new manufacturing processes and new business models” by 2030	- 5G verticals (trials &) initiatives	0 trials identified	
Other (indirectly relevant) targets[274]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	25%[275]	

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)[276]	
	- Number of base stations deployed (progress of deployments	Estimated 100 areas[277]	
	- Network performance: speed	70.44 Mbps[278]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[279]	
-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)[280]	

[274] 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.
[275]€ 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
[276] Telia reports coverage in 50 different locations and regions
[277] Based on Telia announcement in 2021
[278] Estonia's Mobile and Broadband Internet Speeds - Speedtest Global Index
[279]Source: DESI (5G readiness)
[280]Source : DESI (2020 data); Telia reports its 5G networks reaching most of the population and cities in October 2021

	- 5G corridors	Tallin-Riga–Kaunas-Vilnius EE-LV-LT[281]	
-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[282]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[283]	

5.1.9 Finland

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 290 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	3,000[284]	
	- Network performance: speed	204.8 Mbps[285]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	99.2%[286]	

[281] Home - 5g routes project (5g-routes.eu)
[282] 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.
[283] € 204 million (Digitalising companies; Digitalising public administration; Increasing connectivity).
Source: factsheet-estonia_en.pdf (europa.eu)
[284] Source: EC
[285] Benchmarking the Global 5G Experience — September 2021 | Opensignal
[286]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)	In late 2020, 100 Mbps 5G networks covered 17% of Finland's main roads and highways and 18% of the railway network.[287]	
	- Population coverage	67% of Finnish households[288]	
	- 5G corridors	- Nordic Way2 NO-SE-FI-DK [289] - 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[290]	
	- 5G verticals (trials &) initiatives	4 trials identified	
Other (indirectly relevant) targets[291]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	27%[292]	

5.1.10 France

Target	Indicator(s)	Performance	On Track

[287] Fast 5G already available to more than 1.8 million Finnish households | Traficom
[288] Fast 5G already available to more than 1.8 million Finnish households | Traficom
[289] https://www.nordicway.net/
[290] 24.25–25.1 GHz
[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] € 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)

-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)[293]	
	- Number of base stations deployed (progress of deployments	16,807[294]	
	- Network performance: speed	72.47 Mbps[295]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	59.2%[296]	
-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%[297]	
	- 5G corridors	Barcelona-Perpignan, Santander-Biarritz ES-FR [298]	
-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[299]	
	- 5G verticals (trials &) initiatives	3 trials identified	

[293] For instance Bouygues Telecom reports 5G coverage in 5 cities and over 2500 municipalities
[294] Observatoire5G_France_15072021.pdf (arcep.fr)
[295] France's Mobile and Broadband Internet Speeds - Speedtest Global Index
[296] Source: DESI (5G readiness)
[297] Iliad France population coverage. Source: iliad Group - Our presence in France
[298] 5GMED – Future mobility in the Mediterranean Cross Border Corridor
[299] 2575–2615 MHz

Other (indirectly relevant) targets[300]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[301]	

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[302]	
	- Network performance: speed	113.4 Mbps[303]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	100%[304]	
-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%[305]	
	- 5G corridors	- Brenner Corridor IT-AT-DE[306] - Metz-Merzig-Luxembourg FR-DE-LU[307] - CZ-Bavaria: Prague-Munich	

[300] 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.
[301] € 1 billion (digitalisation of companies; digitalisation of schools; digitalisation of public administration). Source: france-recovery-resilience-factsheet_en.pdf (europa.eu)
[302] Source: EC
[303] Germany, August 2021, 5G Experience Report Report | Opensignal
[304] Source: DESI (5G readiness)
[305] Deutsche Telekom to cover 90% of German population with 5G this year (rcrwireless.com)
[306] Home page - 5G CARMEN
[307] 5GCroCo

-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[308]	
	- 5G verticals (trials &) initiatives	17 trials identified	
Other (indirectly relevant) targets[309]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	52%[310]	

5.1.12 Greece

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 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	1,106[311]	
	- Network performance: speed	70.71 Mbps[312]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	99.2%[313]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[308] 3700–3800 MHz & 26 GHz
[309] 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.
[310] € 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)
[311] Source: EC
[312] Greece's Mobile and Broadband Internet Speeds - Speedtest Global Index
[313]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	60%[314]	
	- 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[315]	
	- 5G verticals (trials &) initiatives	2 trials identified	
Other (indirectly relevant) targets[316]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	23.3%[317]	

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[318]	

[314] Greece, July 2021, Mobile Network Experience Report Report | Opensignal
[315] 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.
[316] 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.
[317] € 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)
[318] Source: EC

	- Network performance: speed	218.8 Mbps[319]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	61.1%[320]	
-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%[321]	
	- 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)	1 trial identified	
Other (indirectly relevant) targets[322]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not approved yet	

[319] Benchmarking the Global 5G Experience — September 2021 | Opensignal
[320]Source: DESI (5G readiness)
[321] Press-Details | Hrvatski Telekom d.d. (ht.hr)
[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.

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[323]	
	- Network performance: speed	153 Mbps[324]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	30%[325]	
-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	30.5%[326]	
	- 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	

[323] Source: EC
[324] Ireland, September 2021, 5G Experience Report Report | Opensignal
[325] Source: DESI (5G readiness)
[326] Source: DESI (2020)

Other (indirectly relevant) targets[327]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[328]	

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[329]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	60%[330]	
-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[331]	
	- 5G corridors	Brenner Corridor IT-AT-DE[332]	

[327] 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.
[328] € 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)
[329] Italy's Mobile and Broadband Internet Speeds - Speedtest Global Index
[330] Source: DESI (5G readiness)
[331] Source: DESI (2020)
[332] Home page - 5G CARMEN

-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[333]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	25%[334]	

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)[335]	
	- Number of base stations deployed (progress of deployments	58[336]	
	- Network performance: speed	45.29 Mbps[337]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	33.3%[338]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[333] 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.
[334] € 26.1 billion (development of ultra-fast and 5G netwrosk; digitalisation of businesses; digitalisation of the public administration).
Source: italy-recovery-resilience-factsheet_en.pdf (europa.eu)
[335] 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.
[336] Source: EC
[337] Latvia's Mobile and Broadband Internet Speeds - Speedtest Global Index
[338] 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[339]	
	- 5G corridors	5G-Routes (CAM, Rail, maritime) EE-LT-LV[340]	
-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	
Other (indirectly relevant) targets[341]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[342]	

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)	None	
	- Number of base stations deployed (progress of deployments	17 in test mode[343]	

[339] Source: DESI (2020); In 2021, Tele2 has already launched 5G mobile communication base stations in 15 Latvian settlements
[340] Home - 5g routes project (5g-routes.eu)
[341] 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.
[342] € 232.5 million: businesses digitalisation; digital upskilling; 5G deployment.
Source: latvia-recovery-resilience-factsheet_en.pdf (europa.eu)
[343] Source: EC. Only in test mode, no commercial launches yet.

	- Network performance: speed	63.03 Mbps[344]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[345]	
-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[346]	
	- 5G corridors	- 5G-Routes (CAM, Rail, maritime) EE-LT-LV[347] - 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[348]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[349]	

[344] Lithuania's Mobile and Broadband Internet Speeds - Speedtest Global Index
[345] Source: DESI (5G readiness)
[346] Source: DESI (2020)
[347] Home - 5g routes project (5g-routes.eu)
[348] 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.
[349] € 307 million: tailored technology for the Lithuanian language; customer-oriented services; 5G networks.
Source: com-2021-386-lithuania_factsheet_en.pdf (europa.eu)

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[350]	
	- Network performance: speed	110.67 Mbps[351]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	60.8%[352]	
-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[353]	
	- 5G corridors	Metz-Merzig-Luxembourg FR-DE-LU[354]	
-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	

[350] Source: estimation based on map. Source: Cadastre GSM - Geoportal Luxembourg (geoportail.lu)
[351] Luxembourg's Mobile and Broadband Internet Speeds - Speedtest Global Index
[352] Source: DESI (5G readiness)
[353] Source: DESI (2020); According to Orange, in 2021, 5G will be deployed all over the country
[354] 5GCroCo

Other (indirectly relevant) targets[355]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[356]	

5.1.19 Malta

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 30 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	282[357]	
	- Network performance: speed	62.10 Mbps[358]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	0%[359]	
-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[360]	
	- 5G corridors	None identified	

[355] 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.
[356] € 23.8 million: secure communications; digital services for public; digitise healthcare.
Source: luxembourg-recovery-resilience-factsheet_en.pdf (europa.eu)
[357] 5G Trial Results - Melita Malta
[358] Malta's Mobile and Broadband Internet Speeds - Speedtest Global Index
[359] Source: DESI (5G readiness)
[360] Source: DESI (2020); nationwide coverage reported by Melita

-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[361]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	26%[362]	

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[363]	
	- Network performance: speed	100.48 Mbps[364]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	33.3%[365]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[361] 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.
[362] € 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)
[363] Source: EC.
[364] Netherlands's Mobile and Broadband Internet Speeds - Speedtest Global Index
[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	80% (overall) 29.1% rural[366]	
	- 5G corridors	Antwerpen-Rotterdam-North Sea (Vlissingen) BE-NL[367]	
-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[368]	
	- 5G verticals (trials &) initiatives	4 trials identified	
Other (indirectly relevant) targets[369]	- 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[370]	
	- Network performance: speed	52.28 Mbps[371]	

[366] Source: DESI (2020)
[367] 5G-BLUEPRINT ‹ 5G-PPP
[368] Plans to set aside 3750–3800 MHz
[369] 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.
[370] Source: EC.
[371] Poland'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	0%[372]	
-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) 0% rural[373]	
	- 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[374]	
	- 5G verticals (trials &) initiatives	0 trials identified	
Other (indirectly relevant) targets[375]	- 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

[372] Source: DESI (5G readiness)
[373] Source: DESI (2020)
[374] Considering allocation in 3.5 GHz
[375] 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.

-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[376]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	8.33%[377]	
-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[378]	
	- 5G corridors	Porto-Vigo, Evora-Merida PT-ES[379]	
-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	

[376] Portugal's Mobile and Broadband Internet Speeds - Speedtest Global Index
[377] Source: DESI (5G readiness)
[378] Source: DESI (2020)
[379] 5G-MOBIX

Other (indirectly relevant) targets[380]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[381]	

5.1.23 Romania

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 31 locations (Sept 2021 overview based on Ookla)	
	- Number of base stations deployed (progress of deployments	796[382]	
	- Network performance: speed	257.99 Mbps[383]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	21.3%[384]	
-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	11.7% (overall) 0% rural[385]	
	- 5G corridors	None identified	

[380] 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.
[381] € 1.5 billion: vocational education and training institutions; digital health transition; digital transition of businesses. Source: portugal-recovery-resilience-factsheet_en.pdf (europa.eu)
[382] Source: EC
[383] Internet infrastructure | Invest Romania (gov.ro)
[384] Source: DESI (5G readiness)
[385] Source: DESI (2020)

-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[386]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[387]	

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[388]	
	- Network performance: speed	51.49 Mbps[389]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	66.7%[390]	
-Uninterrupted 5G wireless broadband coverage for all	- ***Urban areas covered (progress of deployments)*** -	***c.f. above***	

[386] 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.
[387] € 2.8 billion: digitalisation of public administration; digitalisation of health; digitalisation of education. Source: factsheet-romania_en.pdf (europa.eu)
[388] Source: EC
[389] Slovakia's Mobile and Broadband Internet Speeds - Speedtest Global Index
[390] 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[391]	
	- 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[392]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[393]	

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[394]	
	- Network performance: speed	57.52 Mbps[395]	

[391] Source: DESI (2020); O2 Slovakia’s launch is expected to have achieved 20% population coverage
[392] 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.
[393] € 466 million: better services for citizens and businesses; digital infrastructure in schools; digitalising businesses. Source: slovakia-recovery-resilience-factsheet_en.pdf (europa.eu)
[394] Source: EC
[395] Slovenia'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	0%[396]	
-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[397]	
	- 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[398]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[399]	

5.1.26 Spain

Target	Indicator(s)	Performance	On Track

[396] Source: DESI (5G readiness)
[397] Source: DESI (2020); Telecom Slovenia reports 32% coverage of 5G
[398] 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.
[399] € 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)

-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[400]	
	- Network performance: speed	28.14 Mbps[401]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	30%[402]	
-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	12.5% (overall) 0% rural[403]	
	- 5G corridors	Barcelona-Perpignan, Santander-Biarritz ES-FR[404]	
-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 [405]	
	- 5G verticals (trials &) initiatives	16 trials identified	

[400] Source: EC
[401] Spain's Mobile and Broadband Internet Speeds - Speedtest Global Index
[402] Source: DESI (5G readiness)
[403] Source: DESI (2020)
[404] 5GMED – Future mobility in the Mediterranean Cross Border Corridor
[405] Reports for industry allocation in 26 GHz

Other (indirectly relevant) targets[406]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	28%[407]	

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[408]	
	- Current usage of 5G pioneer bands in the various EU member states and future plans to make these bands available for 5G	48.9%[409]	
-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	13.6% (overall) 0% rural[410]	
	- 5G corridors	Nordic Way2 NO-SE-FI-DK[411]	

[406] 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.
[407] € 9.8 billion: digital skills training; digitalisation of public administration; digitalisation of business. Source: spain-recovery-resilience-factsheet_en.pdf (europa.eu)
[408] Benchmarking the Global 5G Experience — September 2021 | Opensignal
[409] Source: DESI (5G readiness)
[410] Source: DESI (2020)
[411] Nordicway2

-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 [412]	
	- 5G verticals (trials &) initiatives	3 trials identified	
Other (indirectly relevant) targets[413]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not approved yet	

[412] 3720–3800 MHz
[413] 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.