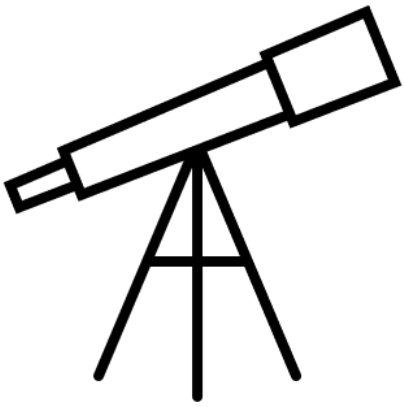
5G Observatory

Quarterly Report 15

Status in March 2022

Study on "European 5G Observatory phase III" (CNECT/2021/OP/0008).



EUROPEAN COMMISSION

Directorate-General for Communications Networks, Content and Technology

NOTE

This is the 15th edition of an independent, quarterly summary of developments in the deployment of 5G in the EU, assessing progress towards policy goals such as the digital dividend. Quarterly publications of the European 5G Observatory have been issued since September 2018, under a contract with the European Union and the opinions expressed are those of (the contractor) and do not represent the official position of the European Commission. Since 2021, the 5G Observatory is run by a consortium of three companies VVA, Policytracker and LS.

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1 What has happened in the past 3 months (focus on EU)

- Operators are still intensifying their efforts to improve 5G and 4G mobile coverage and prepare for new 5G technologies such as OpenRAN.
- More public funding for 5G projects has been announced by the European Commission, France, Italy and Germany.
- EU regulators have come to a political agreement on the proposed "Digital Markets Act", which promise a more levelled playing field between telcos and digital platform actors.

1.1 5G spectrum awards

No major 5G spectrum auctions have taken place in the European Union within the last three months. However, the Austrian regulator RTR did announce plans to award the 26 GHz band in 2023.[1]

Meanwhile, a notable report published by ETNO predicted that mobile operators in Europe will pay around 10% less to acquire 5G spectrum licences compared to 4G licences. The report suggests that operator will pay a total of €34.8bn for 5G spectrum.[2]

Internationally, South Africa completed its long-awaited spectrum award in late March, raising €891 million. Licences were sold in the 700 MHz, 800 MHz, 2.3 GHz, 2.6 GHz and 3.5 GHz bands.[3]

1.2 Policy

In the EU, more countries are announcing funding for 5G related projects. These are listed as follows:

- January 2022: The European Commission announced that it is offering €258 million in funding to support 5G and gigabit network projects.[4]
- January 2022: Germany and France pledged €17.7m for four 5G vertical and cross-border projects.[5]
- March 2022: Italian government announced €2bn in incentives for 5G infrastructure improvements.[6]
- March 2022: German government announced a plan to achieve full 5G coverage by 2030. Plans include speeding up the infrastructure planning process as well as funding for operators who supply underserved areas.[7]

The Council and the Parliament reached a provisional political agreement in March on the Digital Markets Act (DMA), which aims to make the digital sector fairer and more competitive. The DMA aims

[1] https://www.policytracker.com/austrian-regulator-to-award-26-ghz-band-in-2023-despite-uncertainty-about-use-cases/
[2] https://5gobservatory.eu/5g-spectrum-costs-in-europe-10-lower-than-4g/
[3] https://5gobservatory.eu/south-africa-completes-5g-auction/
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[5] https://5gobservatory.eu/germany-and-france-to-fund-private-5g-projects/
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[7] https://5gobservatory.eu/german-government-aims-for-full-5g-population-coverage-by-2030/

to ensure that no large online platform that acts as a 'gatekeeper' for a large number of users abuses its position to the detriment of companies wishing to access such users.

In the US, a disagreement between two federal agencies, the Federal Communications Commission (FCC) and the Federal Aviation Authority (FAA) led to a delay to operators planned c-band 5G rollout. The FAA argued that C-band spectrum would interfere with nearby radio altimeters in aeroplanes. Deployment has since resumed in January 2022.

While the risk of harmful interference is a global issue, the situation in the EU is different. In the EU, the 3.6 GHz band is limited up to 3.8 GHz. Altimeters operate in the 4.2 – 4.4 GHz band. In the US, the upper limit for c-band spectrum is 3.98 GHz, which is much closer to the altimeter range. This means that in essence there is an EU "guard band" of 400 MHz between 5G and altimeter frequencies. The European Union Aviation Safety Agency (EASA) confirms that there have been no reported incidents of harmful interference caused by 5G deployment in the EU.

1.3 Commercial developments

As all EU countries now have at least one operator providing 5G services, the focus for mobile operators has turned to coverage improvements and new technologies such as OpenRAN. The following list details some of these developments:

- Portuguese operator MEO announced in March that its 5G network now covers 50% of the country with 5G.[8]
- ETNO, which represents European mobile operators published a report in February which showed that overall 5G coverage in Europe had nearly doubled from 30% in 2020 to 62% in 2021.[9]
- In Germany, new market entrant 1&1 signalled its intention to launch a 5G network by the end of 2022. The operator will initially use this network for fixed wireless access solutions and later expand to provide mobile services.[10]
- Vodafone group announced in March that it will use Open RAN technology in 30% of its European network sites by 2030.[11]

Internationally, 5G continues to grow. A report published by Counterpoint research in March found that global 5G smartphone sales surpassed 4G for the first time.[12]

Also in March, Apple released a new iPhone SE. This is the first of the low-cost iPhones to support 5G. In the past, iPhone support for new mobile technology has led to higher adoption of said technology.[13]

[8] https://5gobservatory.eu/meo-portugal-says-its-5g-services-cover-50-of-the-population/
[9] https://5gobservatory.eu/report-5g-coverage-doubles-in-europe/
[10] https://5gobservatory.eu/german-operator-11-to-launch-5g-network-by-year-end/
[11] https://5gobservatory.eu/vodafone-targets-open-ran-in-30-of-its-european-network-sites-by-2030/
[12] https://5gobservatory.eu/global-5g-smartphone-sales-surpass-4g-for-the-first-time/
[13] https://5gobservatory.eu/apple-reveals-new-budget-iphone-with-5g/

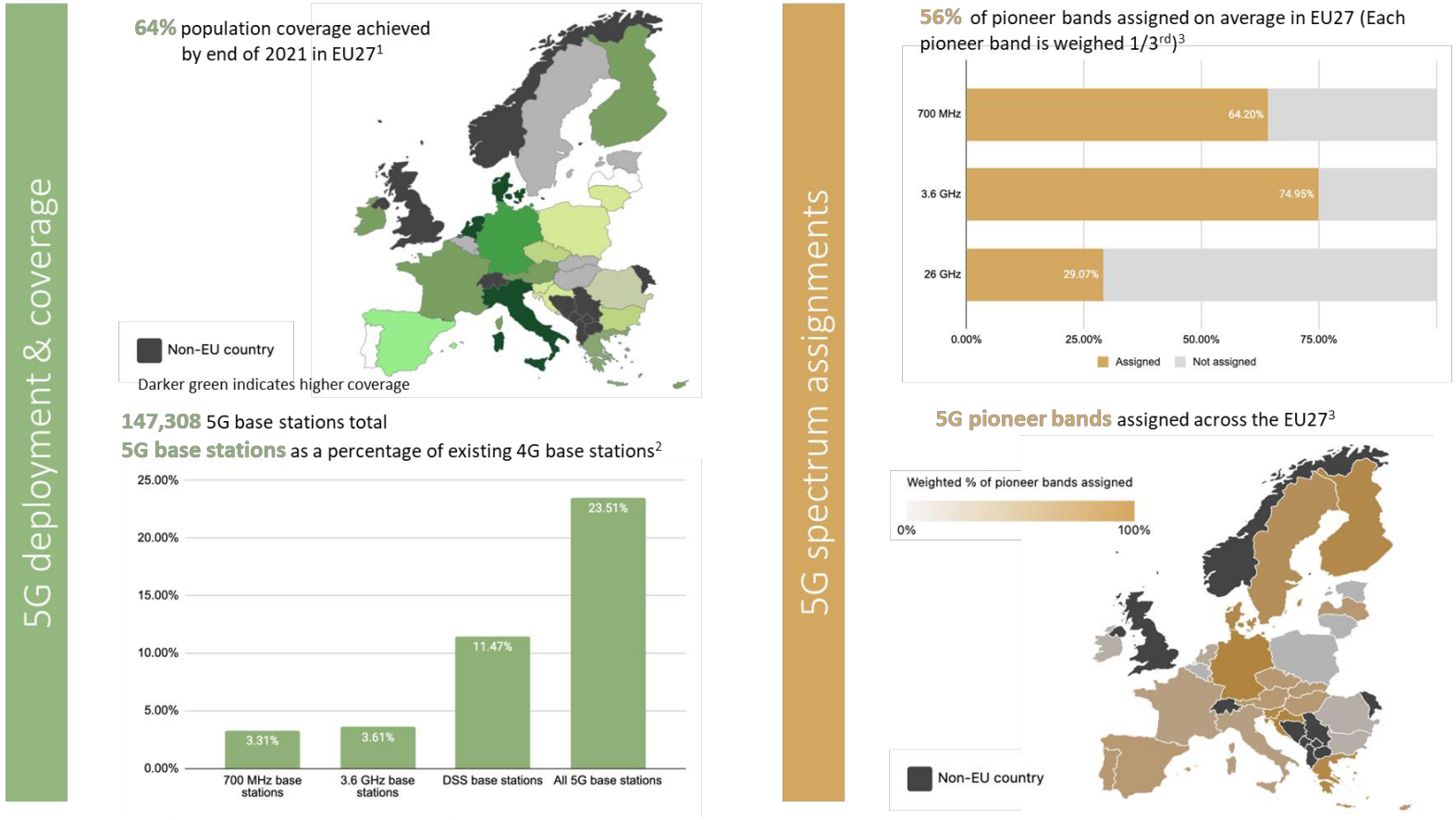
2 5G scoreboard

2.1 EU27 progress so far

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

- All EU countries have now commercial 5G service available at least in a part of the country (please see 0).
- 17 Member States are involved in the preparation of twelve 5G cross border corridors with the aim to stimulate the use of 5G in transport services, in particular to pave the way for Connected and Automated Mobility (please see 0).
- A total of 147,308 5G base stations are now active in the EU.
- The most common type of 5G base station uses 4G bands in a DSS configuration.
- Almost 65% of households across the EU27 were reached by at least one 5G network at the end of 2021[14] (c.f. 0.)
- Please note: Some statistics in this scoreboard may appear lower than in previous reports. This is due to a change in methodology. While previous 5G Observatory scoreboards relied on data collected by the Observatory, all reports from this date on will instead use data collected by the Commission for DESI. This will ensure consistency going forward.

[14] Broadband Connectivity in Europe 2021



(Source: Data of 5G population coverage is based on data from the DESI index. In future quarterly reports, this information will be updated by data collected from the European Commission.

1 - Overall coverage is a general indicator that does not presume any particular quality of service measures. All 5G coverage is included, including that using dynamic spectrum sharing (DSS).

2 - For some EU countries, only the total number of 5G base stations is known. This means the true total number of base stations in the EU in 700 MHz, 3.6 GHz or DSS bands may be higher. Excludes Italy, Estonia and Sweden as there was no base station data available. Additionally, some countries use bands that are not included in this chart and do no operate using a DSS configuration.

3 - Some numbers are lower than previous reports. This is due to a change in methodology. This chart now uses the DESI 5G readiness indicator which is more accurate as it weighs how much spectrum has been assigned into the final score. Previously if a country assigned some spectrum in a band this would show as 100%. Now countries need to assign 60 MHz in 700 MHz; 400 MHz in 3.6 GHz and 1000 MHz in 26 GHz to receive a 100% score.

2.2 International developments

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[15]:

- China has nearly 1 million installed 5G base stations: eight times more than the EU and 18 times more than the USA.
- South Korea has the most 5G base stations per head of population: 13 times more than the EU and 20 times more than the USA.
- South Korea has awarded the most high-band spectrum with a total of 2400 MHz assigned to operators.
- The most widely awarded 5G spectrum in Europe is the mid-band

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

5G rollout

Comparison of 5G rollout in international markets[4]

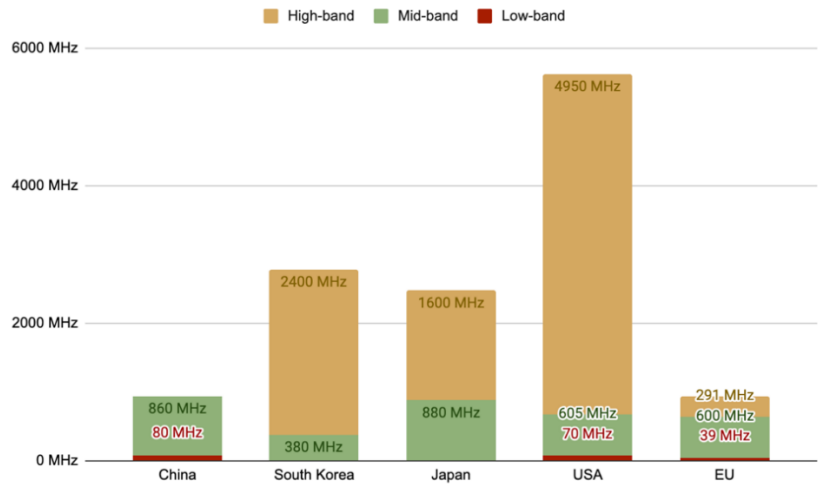
	China	South Korea	Japan	USA	EU
5G Mode	NSA/SA	NSA/SA	NSA/SA	NSA	NSA/SA
Approximate number of 5G base stations	916,000	162,000	50,000	50,000	147,308
Population	1,402,000,000	51,780,000	125,800,000	329,500,000	447,706,000
People per base station	1531	320	2516	6590	3039
Indicative 5G subscribers	**460 million** (source: Ericsson 2021)	**17 million** (source: 5G Forum, Korea)	**14.19 million** (source: Japan times)	**80 million** (including Canada; source: Ericsson 2021)	**31 million** (including all of western Europe; source: Ericsson 2021)

(Source: Data on subscriber numbers and base stations was collected from various sources including regulator announcements.)

4 - There may be discrepancies between the reported figures, as the method for calculating the number of base stations is not standardised between regions

5G spectrum

Assigned 5G spectrum in international markets (EU data represents average spectrum assigned)*



Assigned 5G spectrum bands in international markets*

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	-	3.6 GHz 3.7 GHz 4 GHz 4.5 GHz	28 GHz
USA	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
EU	700 MHz	3.6 GHz	26 GHz

(Source: Data on international spectrum assignments is sourced from the Policy Tracker database, the DESI index as well as FCC data.)

5 - USA data shows all spectrum made available to mobile operators by the FCC. Not all of this spectrum will have been sold to operators so the final amount of spectrum assigned to operators may be slightly lower. For a more detailed explanation of the methodology used see section 5.4.4. For the EU, the data on spectrum assigned has been averaged out across all EU27. Some individual countries may have more spectrum assigned for 5G, while some may have less or none.

***Assigned 5G spectrum bands in international markets** - For the EU, the data on spectrum assigned has been averaged out across all EU27. Some individual countries may have more spectrum assigned for 5G, while some may have less or none.

3 Progress against monitored targets and strategic implications

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 the 5G Action Plan; the Digital Decade policy as well as the EU 5G Cybersecurity Toolbox. This monitoring exercise will represent the basis for a full strategic assessment including relevant roadmaps to be included in the final report:

Targets: 5G AP; Digital Decade; Cybersecurity Toolbox	Performance/status	Bottlenecks identified	Solution/recommendation
Commercial launch of 5G services at least in one major city in all EU countries	Since January 2022, commercial 5G is now available in all 27 EU Member States.[16] All deployments to date cover major cities and urban areas.	None	-
Uninterrupted 5G wireless broadband coverage for all urban areas and major roads and railways.	Based on data collected by the Commission in 2021, the population coverage in the EU is estimated at 64%.[17]	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 proposed Policy Programme "Path to the Digital Decade" which foresees a common EU monitoring mechanism for the attainment of the 2030 targets based on key performance indicators, reported by the Commission in the DESI on a yearly basis.[18, 19]. This edition of the 5G Observatory report also includes a modelling exercise to estimate geographic (populated areas) and transport path coverage.
"Digital technologies including 5G…at the core of new products, new manufacturing processes and new business models"	The roll out of private 5G networks is still in a relatively early growth phase but will be an important contributor to the continued productivity of Member States and adoption of new technologies for enterprises that will support the ongoing development of the 5G ecosystem. 5G verticals appear to be particularly developed in ports, whereas in other industries they are	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.

[16] Final launch in Lithuania announced in January 2020 by Telia

[17] DESI 2022

[18] Source: Proposal for a Decision establishing the 2030 Policy Programme "Path to the Digital Decade"

[19] For more information regarding 5G targets in the digital decade see: https://digital-strategy.ec.europa.eu/en/policies/5g-digital-decade

Targets: 5G AP; Digital Decade; Cybersecurity Toolbox	Performance/status	Bottlenecks identified	Solution/recommendation
	at an earlier stage. Most trials appear to be occurring within private networks although there are some examples of verticals which will run on public networks.		
Authorising 5G spectrum bands	The 3.6 GHz band has been most widely assigned. Twenty one out of 27 Member States have assigned this band. The second most popular band is the 700 MHz band, which has been assigned in nineteen out of 27 Member States. The least popular band is the 26 GHz band, which has only been assigned in seven Member States. Finally, five Member States have failed to assign any of the pioneer bands. A growing trend across Member States is making portions of the C-Band available to private enterprises, such as the dedicated 100 MHz portion available to verticals in Germany or countries such as Sweden and the Netherlands enabling sharing of spectrum to support local network deployments.	Lack of demand for the 26Ghz band. Further development of harmonised approach to spectrum sharing for local networks	Referring specifically to the 26GHz band, there have been differences in the way the band has been made available suggesting there is no "universal formula". Most approaches however take into account the use of the band for industrial applications and 5G verticals.[20]

[20] 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.

Targets: 5G AP; Digital Decade; Cybersecurity Toolbox	Performance/status	Bottlenecks identified	Solution/recommendation
Promoting pan-European multi-stakeholder trials[21]/ 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.[22]	17 of 27 Member States are involved in the existing 12 cross-border corridors.	Upcoming projects (including the support of CEF framework) and commitments of Member States in their recovery plans are expected to bridge existing gaps.
5G toolbox implementation	A large number of Member States have already taken concrete steps to implement the various strategic measures.	Based on the latest NIS report (2020), there are visible differences in terms of implementation maturity for different types of individual measures.[23]	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). A specific NIS report on open RAN architecture is announced for mid 2022.

[21] 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.

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

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

4 5G perspectives: commentary and observations on public initiatives

4.1 Initial reflection on the impact of non-pioneer spectrum usage in 5G rollouts

A key trend in the initial phase of 5G is the use of non-pioneer bands to support 5G rollouts. This editorial considers the factors that are influencing this phenomenon and examines what it means for overall 5G network development.

4.1.1 What spectrum is being used in 5G rollouts?

4.1.1.1.1 Pioneer bands

The use of low-band, mid-band and mmWave frequencies will ultimately be combined in 5G networks to help deliver the full 5G vision. Europe has designated three bands, the 700 MHz, 3.4-3.8 GHz (known as the 3.6 GHz band) and 26 GHz as 5G 'pioneer bands' to help underpinning the initial wave of deployments. Among these, the 3.6 GHz band is seen as foundational for delivering true 5G data rates – what we refer to as 'step-change 5G' – thanks to the use of continuous 80-100 MHz bandwidths that are envisaged per operator.

The timely release of these pioneer frequencies is a key factor determining the progress of 5G network development in Europe. As Table 1 shows, several Members States have yet to award the 700 MHz and 3.6 GHz bands, while only a few have released 26 GHz. However, in many countries the designated low- and mid-bands are now being used in operators' 5G rollouts.

Table 1: Progress with releasing the 5G pioneer bands in Europe

Country	700 MHz	3.6 GHz	26 GHz
Austria	2020	2019	**Not assigned**
Belgium	**Not assigned**	**Not assigned**	**Not assigned**
Bulgaria	**Not assigned**	2021	**Not assigned**
Croatia	2021	2021	2021
Cyprus	2021	2021	**Not assigned**
Czech Republic	2020	2017	**Not assigned**
Denmark	2019	2021	2021
Estonia	**Not assigned**	**Not assigned**	**Not assigned**
Finland	2016	2018	2020
France	2015	2020	**Not assigned**
Germany	2015	2021	**Not assigned**
Greece	2020	2020	2017
Hungary	2020	2020	**Not assigned**
Ireland	**Not assigned**	2017	**Not assigned**
Italy	2018	2018	2018
Latvia	2021	2018	**Not assigned**
Lithuania	**Not assigned**	**Not assigned**	**Not assigned**
Luxembourg	2020	2020	**Not assigned**
Malta	**Not assigned**	2021	**Not assigned**
Netherlands	2021	**Not assigned**	**Not assigned**
Poland	**Not assigned**	**Not assigned**	**Not assigned**

Country	700 MHz	3.6 GHz	26 GHz
Portugal	2021	2021	**Not assigned**
Romania	**Not assigned**	2021	**Not assigned**
Slovakia	2020	**Not assigned**	**Not assigned**
Slovenia	2021	2021	2021
Spain	2021	2018	**Not assigned**
Sweden	2018	2021	**Not assigned**

4.1.1.1.2 Other spectrum

The 5G pioneer bands are not the only frequencies that are being used for 5G. In line with the global trend towards phasing out 2G and 3G networks, the spectrum previously used for these technologies is becoming available for LTE and/or 5G. In Europe, we see particularly the 1800 MHz and 2100 MHz bands starting to be repurposed for 5G, alongside LTE. Some operators are beginning to introduce 5G in other LTE bands, such as 800 MHz and 2.6 GHz. In addition to these legacy frequencies, the 1500 MHz has been awarded in a number of markets and is now being used for Supplementary Downlink (SDL) in 4G/5G networks.

The non-pioneer sub-3 GHz frequencies can help operators to quickly achieve quite widespread 5G coverage, with potential indoor as well as outdoor coverage benefits compared to C-band deployment alone. They may provide an alternative to 700 MHz, for example where the band is not yet available, or supplement that bandwidth.

On the downside, the sub-3 GHz frequencies cannot match the wide bandwidths that are available at 3.6 GHz and so cannot deliver on their own what can be regarded as 'step-change 5G'. Consequently, these frequencies should be seen as complementing the operators' rollouts in the higher pioneer bands, even though at times operators have launched 5G in their legacy frequencies where 5G auctions have suffered delays.

Examples of non-pioneer bands used in 5G networks include:

- Croatia's Hrvatski Telekom used 2100 MHz to roll out 5G with 34% population coverage outdoors, while awaiting the conclusion of the country's 5G auction.
- Vodafone Ziggo launched 5G in the 1800 MHz band ahead of the Netherlands' multi-band auction, achieving 80% population coverage within three months.
- Deutsche Telekom has activated over 63,000 5G base stations and offers over 90% population coverage with 5G running in its 2100 MHz frequencies. Only 3500 of the operator's sites use the 3.6 GHz band. DT planned to close its 3G network in mid-2021, releasing further 2100 MHz bandwidth for LTE and 5G.
- Plus launched Poland's first 5G service using 100 transmitters in the 2.6 GHz band.

4.1.1.1.3 The role of Dynamic Spectrum Sharing

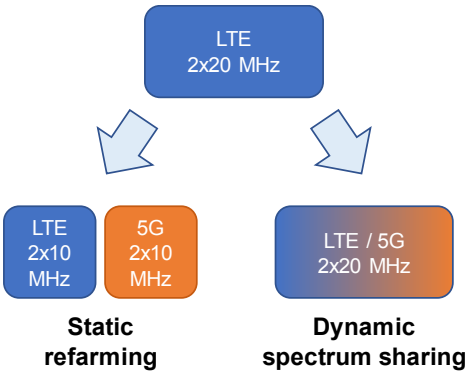
Dynamic Spectrum Technology (DSS) is a software-delivered technology solution offered by the major network vendors to enable dynamic frequency sharing between 5G and LTE (and sometimes 3G too). It offers an alternative to traditional refarming methods, which involve statically partitioning the bandwidth between different mobile technologies (see Figure 1).

One of the potential benefits of deploying 4G/5G DSS is that operators do not need to wait for a mass adoption of 5G handsets before they roll out 5G in an LTE band, as they would have done in the past for

new technologies. This can help operators accelerate their 5G rollouts, as well as optimising the spectrum's overall use.

Many operators worldwide are now using DSS for sharing their spectrum between 4G and 5G. The use of DSS goes beyond the legacy LTE bands. The technology is also being deployed in the 700 MHz band, so that operators can use the spectrum to benefit their LTE users while 5G adoption is still relatively low.

Figure 1: Comparison of static refarming and DSS



4.1.2 Is all 5G equal and does it matter?

The mix of spectrum that is being used for 5G in this early phase of deployment has several effects:

- There can be big differences in the 5G user experience depending on the spectrum used. Step-change 5G – or what some operators refer to as 'true 5G', 'pure 5G' or 5G+ – is available largely where 3.6 GHz is in use, which tends to be in cities and larger towns initially. Where 5G is deployed in 700 MHz or legacy sub-3 GHz spectrum, there is typically a more basic 5G service, with lower data rates. Operators may reflect these differences by differentiating between '5G' and '5G+' coverage areas, so that their customers know to expect differences in their user experience depending on the location.

- Where sub-3 GHz frequencies are used, operators can more rapidly achieve extensive 5G coverage than they can with C-band. In some cases, they have offered 5G across a very wide footprint right from launch, albeit with lower data rates than in their C-band coverage areas.

These factors make it difficult to compare operators' 5G rollouts using just population coverage metrics, headline data rates or the number of base stations deployed. For example, we cannot infer that an operator with 40% 5G population coverage is lagging another whose coverage is 80%. What seems to be a vast difference in progress may instead reflect a different use of spectrum and alternative rollout strategy. Similarly, it can be difficult to evaluate how one country is faring against another using simple coverage or base station metrics.

As an illustration, Italy's WIND Tre has one of the most extensive 5G networks in Europe, offering 96% population coverage. By comparison, the other Italian operators have 5G coverage in large towns and cities and other touristic areas. These coverage differences reflect the operators' chosen 5G strategies, as well as certain aspects of their spectrum portfolios. WIND Tre has achieved very high population coverage, using 1800 MHz and 2.6 GHz spectrum to complement its C-band deployment. With 3.6 GHz, its coverage is much lower, at just over 50% – hence broadly comparable with its competitors. Another difference in terms of spectrum is that Iliad, TIM and Vodafone will gain access in mid-2022 to the 700 MHz frequencies they bought at auction, which will enable them to roll out wide-area 5G coverage, but

WIND Tre does not have a 700 MHz licence and so needs an alternative strategy for achieving blanket coverage.

The contrasting approaches in Italy to 5G rollout are also apparent in the experienced 5G download rates. According to user data gathered by Opensignal, TIM customers enjoy the highest 5G download rates by some margin. This is in keeping with the operator's 5G strategy, which is to offer what it calls 'true 5G'. WIND Tre has the market's lowest 5G download rates, reflecting a drop in the data rates outside its C-band coverage area.

Table 2: Comparison of 5G coverage and download speeds, Italy

	Iliad	TIM	WIND Tre	Vodafone
5G coverage	27 towns & cities	Major towns & cities & tourist locations	96% (FDD bands); 50% (TDD)	Around 25 towns & cities
5G download speeds*	103.5 Mbit/s	273.7 Mbit/s	64.7 Mbit/s	126.2 Mbit/s

* Source: Opensignal 5G user experience reports

Turning to France, ARCEP's 5G deployment data shows that Free Mobile has at least double the number of commercially launched 5G sites compared to the other operators, but the number of 3.5 GHz sites is broadly similar for all the operators (see Table 3).

When it comes to the experienced 5G download rates, Opensignal's user-sourced metrics show that Free Mobile and Bouygues Telecom have slower speeds compared to SFR and Orange. This clearly reflects the differences in the frequencies used in the operators' 5G deployments.

Table 3: Active 5G sites in France by frequency band, year-end 2021

Number of 5G sites	Bouygues Telecom	Free Mobile	Orange	SFR
700 & 800 MHz	0	13,470	0	0
1800 & 2100 MHz	6468	0	471	2156
3500 MHz	2689	2384	2698	2828
Total 5G sites	**6730**	**13,470**	**3035**	**4984**
5G DL rates	121.6 Mbit/s	98.1 Mbit/s	272.7 Mbit/s	183.8 Mbit/s

Source: ARCEP 5G Observatory; Opensignal 5G experience reports

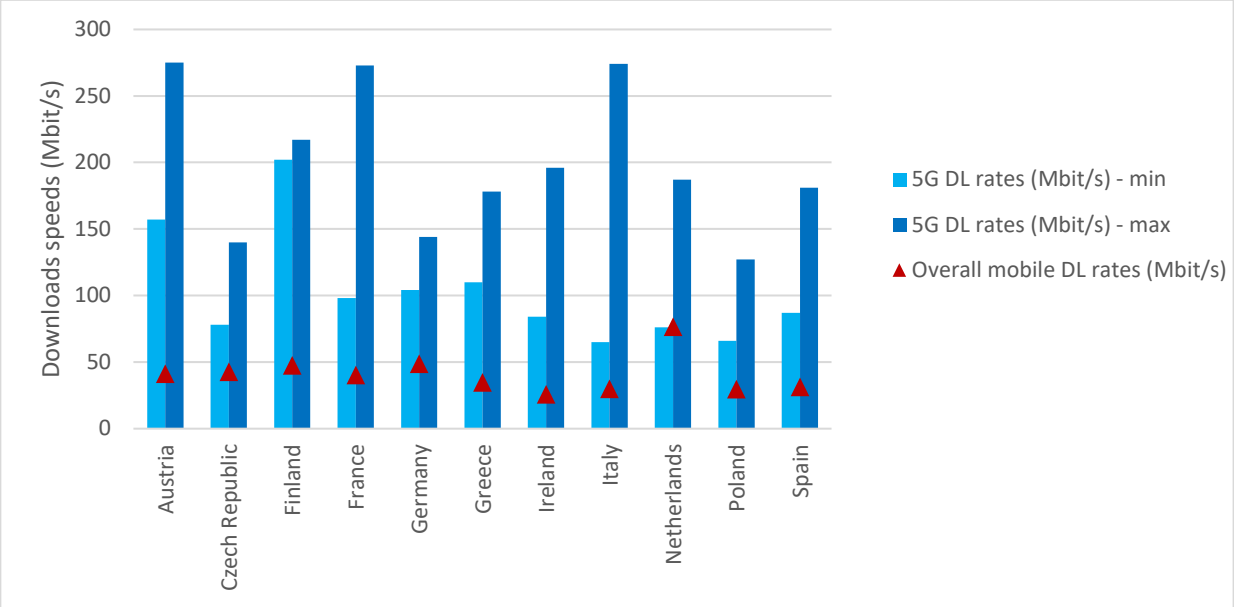
Note: Multiple bands may be used at the same site. Data for 5G experienced download speeds is sourced from Opensignal.

A key question is how much do these current differences between 5G deployments matter. We do not expect these divergences in 5G coverage and user experience to be enduring in the long run. The variations we see now arise from the different paths operators are choosing to arrive at a common end-goal of having fully developed national 5G networks in a few years' time.

It is also worth noting that even where sub-3 GHz spectrum is contributing significantly to 5G rollout, end-users are seeing improvements in mobile service. Based on Opensignal's data, the figure below compares the average mobile network download speeds (across all network technologies) with the lowest and highest average 5G-only download speeds among the operators for selected European countries. The chart shows a step-change in the user experience on 5G networks compared to the mobile

networks overall. Only in the Netherlands is the minimum 5G download speed among the operators on a par with the country's overall mobile download speeds – which is the highest in Europe.[24]

Figure 2: Comparison of 5G and overall mobile download speeds, selected European markets



Source: data sourced from Opensignal 5G experience reports

4.1.3 Evaluation

To help shed light on the role of non-pioneer bands in 5G networks, we have compared a number of mobile network and spectrum indicators.

Firstly, we have assessed the extent to which non-pioneer frequencies are being used in each country. For a few countries, such as France, there is reported data on the number of base stations in each band, but for most Member States such detailed and up-to-date information is lacking. In those cases, we have used operator statements to develop a picture of the extent to which the current 5G rollouts are using the non-pioneer spectrum bands. We categorise countries where at least one operator is making a notable use of the non-pioneer frequencies as having a 'more important' level of such use. Countries where the operators' rollouts appear to rely more on the pioneer bands are considered to have 'less important' non-pioneer band use. That doesn't mean there is no such use. It is also important to remember that this is just a snapshot of the current situation, and the picture is likely to change as 5G rollouts progress.

We have also evaluated how quickly each Member State has awarded the 700 MHz and 3.6 GHz pioneer bands and launched 5G, relative to the average rates across the EU27.

Finally, we have benchmarked the average mobile data rates (across all network technologies) against the EU27 average, drawing on raw data from Opensignal. This provides an indication of the overall level of mobile network development.

Taking all these indicators together, we can make several observations:

[24] However, it can also be noted that download speeds are not the only relevant parameter. Higher frequency bands also enable other performance improvements like response time or geo-localization, or upload speeds using MIMO.

- Where MS have been slower to release 700 MHz and 3.5 GHz spectrum, most countries show a 'more important' extent of non-pioneer band use in their 5G rollouts. This is not unexpected, and reflects that operators have been able to draw on their existing spectrum holdings to overcome delays in new bands becoming available. Two further factors are particularly significant here: first, the phasing out of 2G/3G networks is freeing up existing bandwidth for upgrading to newer technologies; second, DSS de-risks an early introduction of 5G in such frequencies, as spectrum can be dynamically shared with LTE to optimise the overall use of the available frequencies.

- There are a few countries where there is a notable use of the non-pioneer bands, despite a 'faster' release of the 700 MHz and/or 3.6 GHz frequencies – for example, the Czech Republic, France, Germany, Hungary, Italy and Spain. Again, 2G/3G network sunsets are likely a factor here, freeing up spectrum for the deployment of the latest technologies – for example, all three mobile operators in the Czech Republic have closed their 3G networks. In countries like Germany and Hungary, another factor is that the 2100 MHz bands have been re-awarded, which provides the licensees with the long-term certainty they need to invest in network development. As previously noted, the non-pioneer bands may also have a particular relevance for developing 5G coverage if operators lack other suitable spectrum (e.g. 700 MHz).

- Members States with 'more important' use of non-pioneer spectrum for 5G tend to have below average overall mobile download speeds (across all technologies), but there are some notable exceptions. For example, the Netherlands has the highest overall mobile downloads speeds, despite the C-band auction continuing to be delayed. Germany also has above average overall mobile data rates, notwithstanding the significant use there of non-pioneer spectrum. What is likely relevant here is that both DT and Vodafone have *extensive* DSS rollouts, which help boost data rates across a wide area. For example, Vodafone Germany noted that its 4G/5G DSS deployment in the 700 MHz band would offer data rates of 200Mbit/s, which it claimed would be 20 times faster than previously in locations with poor existing coverage.

Table 4: Comparison of non-pioneer spectrum use in 5G rollouts and selected mobile indicators

Country	Speed of spectrum awards (700 MHz & 3.6 GHz)	Speed of 5G network launch	Use of non-pioneer bands	Average mobile download speeds*
Austria	Faster	Faster	Less important	Above average
Belgium	Slower	Faster	More important	Below average
Bulgaria	Slower	Slower	More important	Above average
Croatia	Slower	Slower	More important	Above average
Cyprus	Slower	Slower	Less important	*No data*
Czech Republic	Faster	Slower	More important	Above average
Denmark	Faster	Faster	Less important	Above average
Estonia	Slower	Slower	More important	Below average
Finland	Faster	Faster	Less important	Above average
France	Faster	Slower	More important	Below average
Germany	Faster	Faster	More important	Above average
Greece	Faster	Slower	More important	Below average
Hungary	Faster	Faster	More important	Below average
Ireland	Slower	Faster	More important	Below average
Italy	Faster	Faster	More important	Below average
Latvia	Faster	Faster	Less important	Below average
Lithuania	Slower	Slower	More important	Above average

Country	Speed of spectrum awards (700 MHz & 3.6 GHz)	Speed of 5G network launch	Use of non-pioneer bands	Average mobile download speeds*
Luxembourg	Faster	Slower	Less important	*No data*
Malta	Slower	Slower	Less important	*No data*
Netherlands	Slower	Faster	More important	Above average
Poland	Slower	Slower	More important	Below average
Portugal	Slower	Slower	Less important	Above average
Romania	Slower	Faster	More important	Below average
Slovakia	Slower	Slower	More important	Below average
Slovenia	Slower	Slower	More important	Below average
Spain	Faster	Faster	More important	Below average
Sweden	Faster	Slower	Less important	Above average

Note: Average mobile download rates across all network technologies; raw data sourced from Opensignal.[25]

4.1.4 Conclusions

In summary, our analysis of non-pioneer spectrum use in Europe's 5G rollouts has found that:

- Two-thirds of the EU Member States have a notable use of non-pioneer spectrum for 5G network deployment. Such frequencies generally complement deployments in 700 MHz and 3.6 GHz, but operators have frequently taken advantage of their existing spectrum resources to launch 5G where the release of the pioneer bands has been delayed.

- Not all mobile operators favour using the non-pioneer bands for 5G at this stage of deployment. Some – such as TIM and O2 Germany – are focusing instead on developing step-change 5G based on the 3.6 GHz band. However, eventually 5G will be deployed in all the FDD bands.

- The closure of 2G/3G networks is freeing up bandwidth for use by newer technologies, namely LTE and 5G. 4G/5G DSS solutions remove any need for operators to choose one technology over the other: they can support both, as the spectrum use can dynamically adapt as the balance of 4G and 5G traffic changes. This helps accelerate the introduction of 5G in the former 2G and 3G bands.

- The use of sub-3 GHz spectrum for 5G (usually with 4G/5G DSS and including the 700 MHz band) is typically reflected in lower 5G data rates and more extensive coverage compared to C-band-only deployments. In practice, the two types of deployment are usually combined, and this will be increasingly the case in the future.

4.2 5G Deployment Forecasting progress towards 2025

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

[25] Opensignal, 5G Impact on the Global Mobile Network Experience, February 2022.

4.2.1 Analysys Mason, Costs and benefits of 5G geographical coverage in Europe[26], 2021. Scope: EU27

Methodological framework/approach

Building on a previous study conducted in 2020, 5G investment in Europe and associated costs and benefits were modelled under three deployment scenarios and for 13 different use cases. The scenarios are as follows:

- Scenario A: The cost and extent of commercially led 5G enhanced mobile broadband (eMBB) roll-out in different European markets (using a combination of new 5G pioneer plus legacy mobile bands), referred to as the 5G 'base case'
- Scenario B: The additional investment needed to deliver near-universal geographical coverage using a low-frequency 5G layer (700MHz), referred to as the 'low-frequency 5G case'
- Scenario C: The additional investment needed to extend 3.5GHz mid-band coverage beyond the base case to cover road, rail and rural use cases (including fixed wireless access into homes and businesses, and smart agriculture), referred to as the 'full-5G mid-band coverage case'

The 13 use cases are as follows: urban high-capacity locations ('urban hotspots'); construction; broadband into homes and offices delivered via 5G fixed-wireless access (FWA); agriculture; road; rail; smart factories; mining; ports; airports; energy and utilities; healthcare and hospitals; municipal buildings.

Outcome summary

- Scenario A:

Enhanced mobile broadband (eMBB) roll-out by multiple Mobile Network Operators (MNOs) will total EUR 4-10 billion per network in the largest markets. Across Europe as a whole, the investment will be around EUR 150 billion.

The modelling suggests that MNOs will deploy 3.5 GHz on a commercial basis to achieve c.30-60% population coverage by 2026.

- Scenario B:

Extending 5G coverage to near-universal geographical coverage using 700MHz might result in an additional single network cost of EUR 4 billion (as a best-case estimate, featuring cooperation between industry and policy makers to achieve a roll-out structure minimising duplication of network)

- Scenario C:

A total additional investment of EUR 20 billion across Europe needed to cover road, rail and agricultural areas (also providing coverage for fixed-wireless access [FWA] and construction use cases).

This assumes that the same 3.5GHz 5G infrastructure can be shared by different use cases (while meeting the specific requirements of each use case) and that a single multi-use case network would be shared by operators outside of commercial areas.

26GHz deployment alongside 3.5GHz will be especially useful for 5G FWA use.

[26] Analysys Mason 2021

4.2.2 GSMA, The Mobile Economy Europe – 2021[27], 2021. Scope: Europe

Methodological framework/approach

Representing the interests of mobile operators worldwide, the GSMA is considered an industry reference point of global mobile operator data, analysis, and forecasts, publishing annually industry reports and research. GSMA's annual state of mobile economy reports (global and regional versions) provide market intelligence (technology, socio-economic and financial datasets) through their in-house research team (i.e. proprietary models/forecasting methodology and datasets).

Outcome summary

In 2020, 472 million people in Europe (86% of the population) subscribed to mobile services. Eastern and Southern European Countries will the fastest growth rates of subscriptions by 2025 (reaching 480 million), which will still be modest compared to those of Latin America or Sub-Saharan Africa.

In European markets, the number of mobile internet users is expected to surge throughout the region, quadrupling overall by 2026.

By the end of 2025, Europe will feature 276 million 5G connections, with the Nordic and Western Europe recording the highest adoption rates. In Europe, the 5G adoption (percentage of total connections) in 2025 is expected to be 40%.

Operator investment to support 5G rollout will total EUR 145 billion by 2025.

4.2.3 Ericsson, Mobility report[28], 2021. Scope: Global

Methodological framework/approach

The forecast models are established using historical data from various sources, validated with Ericsson internal data, including measurements in customers networks and industry analyst reports. Future developments are estimated on macroeconomic trends, user trends, market maturity and technological advances.

Outcome summary

5G is expected to be the fastest-deployed mobile communication technology in history and is forecast to cover about 75 % of the world's population in 2027. In addition, it is expected that 5G will account for nearly half of all mobile subscriptions by 2027 (4.4 billion, 49 %).

Western Europe is expected to reach 430 million of 5G subscriptions by 2027, while Central and Eastern Europe will reach 230 million in the same period.

4.2.4 Dialogic, Study for the Dutch Ministry of Economic Affairs and Climate[29], 2021. Scope: Netherlands

Methodological framework/approach

Demand for new antennas was modelled by comparing expected demand for mobile network capacity (distinguishing between 3 growth scenarios), with expected capacity offered by the current networks, and considering technological upgrades and deployment of new spectrum (e.g. 3.5 GHz and 26 GHz bands). This results in an accurate estimation of the number of base stations likely to encounter a capacity bottleneck between 2021 and 2026. For these base stations, further analysis was performed to determine how many new base stations would be required to provide the demanded capacity. The

[27] GSMA, The Mobile Economy – Europe 2021
[28] Ericsson, Mobility Report 2021
[29] Study for the Dutch Ministry of Economic Affairs and Climate

results are then translated to a number of antenna sites, in order to account for potential site sharing between the operators.

Outcome Summary

Between 296 and 726 new antenna sites need to be deployed by 2026 to fulfil requirements set by Dutch regulator.

4.2.5 European Commission Staff Working Document accompanying the 2030 Policy Programme "Path to the Digital Decade"[30], 2021. Scope: EU27

Methodological framework/approach

The projected 5G coverage growth is based on an increase of the planned investments in 5G infrastructure (by an approximate factor of 25%) to fill in the estimate investment gap to reach the set deployment target by 2030. 5G coverage is projected using the historical evolution of 4G coverage (2011-2020) taking into account completed and planned spectrum assignments.

Outcome summary

80% of population will be covered by 5G in 2025 with all populated areas covered by 2030.

4.2.6 Northstream, 5G Outlook in Europe[31], 2019. Scope: 4 EU Member States (Germany. France, Italy, and Spain) + UK

Methodological framework/approach

A theoretical 5G rollout on mid-band spectrum was modelled in terms of population coverage for the respectively largest operator across seven countries: US, Japan, Germany, France, Italy, UK and Spain. While US and Japan were expected to lead in deployment pace, the European countries were forecasted to be relatively slower. For the purpose of the study, the analysed European countries (with UK still part of the EU at the time of the analysis) were chosen as representative for Europe because they were the only ones that already assigned mid-band spectrum to MNOs when the study began.

Outcome summary

In terms of population coverage for the projected 5G network rollout, 95% population coverage was expected to be reached by EU countries analysed by 2023/2024. The same level of coverage was projected to be achieved 3 years earlier (2020/2021) in the US and Japan.

[30] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2021:0247:FIN:EN:PDF
[31] Northstream, 5G Outlook in Europe

Annex I: Latest developments per country

Latest commercial developments

Since January 2022, commercial 5G is now available in all 27 EU Member States.[32]The full 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 is available on the European 5G Observatory website. This information is updated regularly. Below is a summary of the main changes compared to the previous edition of the report:

- Belgium:
    - Orange Belgium announced the activation in Antwerp of the operator's first 5G sites. Using temporary spectrum provided by the regulator, Orange Belgium plans to extend coverage to the cities of Ghent, Bruges, Leuven and coastal areas in the Flanders region over the coming months.
- Denmark:
    - Telenor announced its plan for 2022, featuring the update of additional 1,400 masts to 5G and the start of the deployment of a Standalone 5G network.
- Finland:
    - Elisa Oyj announced its 5G network operating in the 3.6 GHz band frequencies is currently available in 158 locations in Finland, covering more than 70% of Finns. The operator plans to further extend its network in southern Finland.
- France:
    - The French operator Free reports its 5G network currently covers 79% of the population in France in the 700 MHz and 3.5 GHz frequencies.
    - The French operator SFR revealed that its 5G network coverage currently reaches 52% of the population, with 5G services present in the 32 largest cities.
- Germany:
    - The German operator 1&1 announced the deployment of its network by the end of 2022, becoming Germany's fourth mobile operator launching 5G services.
    - With a total of 18,000 5G antennas at 6,000 locations, Vodafone Germany declared its 5G network is available for around 45 million people in Germany. 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. Moreover, the 3.5 GHz band is being rolled out in high traffic areas.
    - Vodafone Germany announced it put its first 5G Standalone (5G SA) radio small cells in operation in the city of Cologne. The so-called '5G+' small cells are aimed at providing additional capacity and increasing coverage to the existing mobile network

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

in dense urban areas. Vodafone Germany plans to expand its 5G SA network with a view to achieving almost nationwide coverage by 2025.

- Telekom Deutschland, the domestic fixed and mobile unit of Deutsche Telekom, announced the addition of 159 new 5G locations last month, bringing the 5G antenna total to more than 63,000 to provide coverage to 90% of the population. The total includes 4,000 antennas in over 180 cities and municipalities in the 3.7GHz band. Telekom revealed that it also plans to use its 700MHz spectrum for 5G Standalone (5G SA) this year.
- Deutsche Telekom reported 5,000 antennas are now compatible with standalone (SA) 5G in the 3.6GHz band, although the German operator is yet to reveal when it will commercially launch the advanced service. In addition, Deutsche Telekom declared the addition of 350 new sites to its SA 5G footprint in recent weeks, raising the total number of sites to 1,700.
- Telefonica Deutschland (O2) announced that it is now providing 5G coverage to one-third of the German population, via 10,000 5G antennas. Of this figure, 5,000 cell sites are said to utilise the 3.6GHz band. Elsewhere, the 700MHz band is primarily being used to deliver 5G coverage to rural communities. Telefonica noted that the 5G rollout will be complemented by the use of Dynamic Spectrum Sharing (DSS) technology via the 1800MHz band. In addition, by the end of 2022 Telefonica plans to cover 50% of the population with its 5G network, with nationwide coverage expected to be achieved by end-2025.

- Lithuania:
  - Following the ruling of the Lithuanian regulator allowing operators to use existing spectrum holdings for 5G, Telia will be able to roll out 5G services in other bands, including the 2.1 GHz and 2.5 GHz bands.
- Portugal:
  - The Portuguese operator MEO, who launched 5G services at the beginning of 2022, announced its 5G network currently covers 50% of the population.
- Slovakia:
  - O2 Slovakia added dozens of new locations to its 5G network, which now covers 64 cities, towns and villages. The operator foresees to have 5G services available in all regional centres by the end of 2022.
- Spain:
  - Vodafone Spain announced its plan to cover 46% of the population with its 5G coverage by the end of 2022 by using the 700MHz, 3.5GHz or both frequency bands.
  - Orange Spain announced it expects to reach 90% coverage through a combination of NSA 5G architecture and Dynamic Spectrum Sharing technology by 2022. The operator reported the full-scale activation of 5G services on the 700 MHz band. Currently, the operator's network has a 5G coverage of 58.6% of the Spanish population
  - The Spanish operator Telefonica announced it switched on 5G in the 700 MHz band complementing its population coverage, which now reaches more than 80%. Telefonica plans to reach 1,400 municipalities by 2022 and 2,400 by 2023.

Population coverage

As already introduced in previous editions of this report, 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 (with the breakdown per member state).

Some values regarding the population coverage may appear different than in previous reports. This is due to a change in methodology. While previously, the 5G Observatory relied on data collected by the Observatory, all reports from this date on will instead use data collected by the Commission for DESI. This will ensure consistency going forward.

The estimated coverage figure for EU27 (**64%**) in the table below is based on the sum of total number of people covered in each country (computed based on the percentage of population covered, obtained from operator/regulator reports where data was available) divided by the total EU27 population[33, 34].

Table 5: Population coverage

Country	Population coverage (2021-Q1 2022)	People covered (estimation 2021 2021-Q1 2022)	Note (2021/Q 1 2022 figure)
Austria	76,8%	6.860.286	EC
Belgium	4,3%	491.557	EC
Bulgaria	40,1%	2.773.536	EC
Croatia	33,8%	1.364.288	EC
Cyprus	75%	672.004	EC
Czechia	49,4%	5.286.678	EC
Denmark	98,8%	5.769.964	EC
Estonia	18,3%	243.402	EC
Finland	71,6%	3.962.196	EC
France	74,4%%	50.175.062	EC
Germany	86,5%	71.929.102	EC
Greece	66,1%	7.061.164	EC
Hungary	17,6%	1.712.616	EC
Ireland	72,1%	3.609.980	EC
Italy	99,7%	59.079.793	EC
Latvia	0%	-	EC
Lithuania	33,3%	930.961	EC
Luxembourg	12,7%	80.611	EC
Malta	20%	103.220	EC
Netherlands	97%	16.951.153	EC
Poland	34,2%	12.941.280	EC
Portugal	0%	-	EC
Romania	24,9%	4.777.364	EC
Slovakia	13,8%	753.450	EC
Slovenia	36,6%	771.886	EC

[33] Population statistics for 2021 accessed via Eurostat

[34] This figure can be contextualised based on the latest population coverage figure estimated by ETNO, although not directly comparable, the latter one also covering non-EU countries, e.g. UK, Switzerland, Norway, Iceland and Western Balkans (62% in Q3 2021). Source: ETNO State of Digital 2022

Country	Population coverage (2021-Q1 2022)	People covered (estimation 2021 2021-Q1 2022)	Note (2021/Q 1 2022 figure)
Spain	58,9%	27.915.197	EC
Sweden	17,7%	1.837.135	EC
EU 25	66%	288.053.884	Calculation only considering countries where information was available.
EU 27	**64%**	**As above**	

5G sector comparison between EU and other world regions

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.[35] 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 147,308 base stations. This works out to 3039 people per base station.

In terms of assigned 5G spectrum, the 3.6 GHz band has proven to be the most used 5G band globally. All four countries in this comparison have assigned this valuable mid-band spectrum. The 28 GHz band is also well adopted, and it has been assigned in South Korea, Japan, and the USA. In the EU the situation is a little more complex as each country assigns their own spectrum. However, most countries have assigned at least the 3.6 GHz band for 5G deployment, while only 7 EU MS have assigned the 26 GHz band for which the demand has been lowest so far. See the spectrum assignment chart in 2.2.

5G Spectrum comparison between EU and other world regions

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.

No major 5G spectrum awards have taken place in the European Union within the last three months. The 3.6 GHz band remains the most widely assigned 5G band in Europe.

A new international comparison of total spectrum assigned reveals that China has assigned the most mid-band spectrum.

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

Overview of pioneer bands

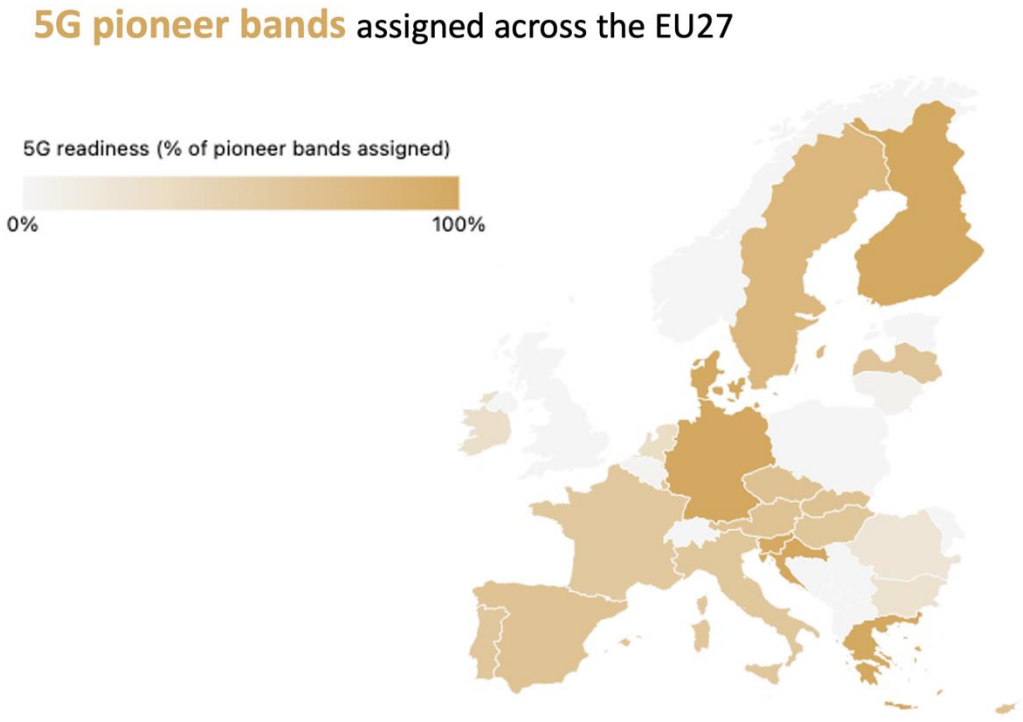
In 2016, with the release of the 5G Action Plan, the EU Commission proposed establishing a list of pioneer spectrum bands for the initial launch of 5G services. It proposed bands in three categories: below 1 GHz, between 1 GHz and 6 GHz and above 6 GHz.

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.

EU27 trends



Source: Spectrum assignment data is based on the results of a European Commission survey of all 27 EU countries.

Pioneer bands assigned

The table below outlines how much spectrum each Member State has assigned in the pioneer bands. To achieve 100%, a country must assign 60 MHz in the 700 MHz band; 400 MHz in the 3.6 GHz band and 1000 MHz in the 26 GHz band. The percentages displayed present how much spectrum has been assigned to operators compared to these numbers.

Amongst Member States, the 3.6 GHz band has been most widely assigned. 22 out of 27 Member States have assigned at least 50% of the targeted spectrum in this band. The second most assigned band is the

700 MHz band, which has been majority-assigned in 18 out of 27 Member States. The least assigned band is the 26 GHz band. The 26 GHz band has only been majority-assigned in eight Member States. Finally, five Member States have failed to assign any of the pioneer bands.

Table 6: Pioneer bands assigned in the EU[36]

Country	% of band assigned		
	700 MHz	3.6 GHz	26 GHz
Total harmonised spectrum (100%)	60 MHz	400 MHz	1000 MHz
Austria	100.0%	97.5%	0.0%
Belgium	0.0%	10.0%	0.0%
Bulgaria	0.0%	75.0%	0.0%
Croatia	100.0%	100.0%	100.0%
Cyprus	100.0%	100.0%	0.0%
Czech Republic	100.0%	100.0%	0.0%
Denmark	100.0%	97.5%	100.0%
Estonia	0.0%	0.0%	0.0%
Finland	100.0%	97.5%	100.0%
France	100.0%	77.5%	0.0%
Germany	100.0%	100.0%	100.0%
Greece	100.0%	97.5%	100.0%
Hungary	83.3%	97.5%	0.0%
Ireland	0.0%	87.5%	0.0%
Italy	0.0%	80.0%	100.0%
Latvia	100.0%	87.5%	0.0%
Lithuania	0.0%	16.3%	0.0%
Luxembourg	100.0%	82.5%	0.0%
Malta	0.0%	75.0%	0.0%
Netherlands	100.0%	0.0%	0.0%
Poland	0.0%	0.0%	0.0%
Portugal	83.3%	100.0%	0.0%
Romania	0.0%	65.0%	0.0%
Slovakia	100.0%	100.0%	0.0%

[36] Source: European Commission data collected for The Digital Economy and Society Index (DESI)

Slovenia	100.0%	95.0%	100.0%
Spain	100.0%	95.0%	0.0%
Sweden	66.7%	90.0%	85.0%
Number of countries that have assigned at least 50% of the band	18	22	8

International trends in spectrum allocation

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

Although there are international discrepancies on which bands are used in each category, classifying the spectrum in this way allows for an easier international comparison of the state of 5G spectrum harmonisation and assignment. The following table provides an overview of which spectrum bands are assigned for 5G in various international markets.

Table 7: 5G bands awarded in major economies outside of the EU[37]

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	-	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 - 3.7 GHz 3.7 - 3.98 GHz	24 GHz 28 GHz 39 GHz 47 GHz
EU	700 MHz	3.6 GHz	26 GHz

[37] Source: Source: Data on international spectrum assignments is sourced from the Policy Tracker database.

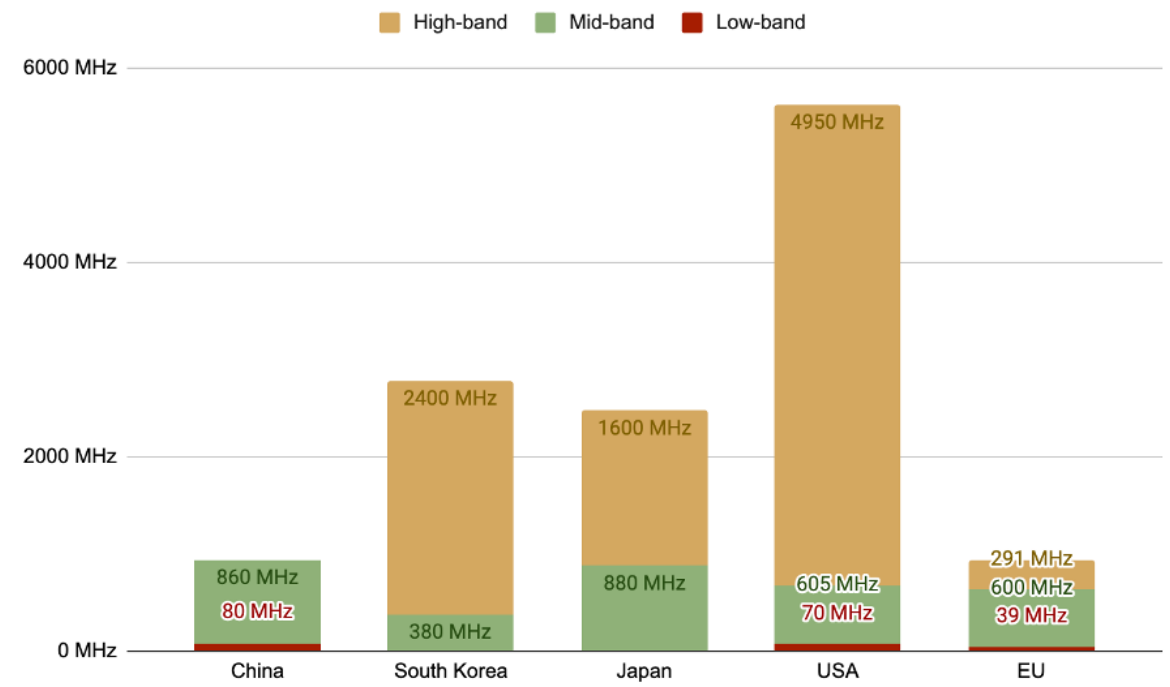
Internationally, mid-band 5G spectrum has been established as the workhorse band for 5G. It has been assigned in most major markets including China, South Korea, Japan and the USA. Japan is leading with mid-band 5G assignments. The country has allocated 880 MHz of spectrum in the band for 5G services. China comes in second with 860 MHz assigned. An average EU country has 600 MHz of mid-band spectrum assigned.

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.

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. 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. The United States leads with 4950 MHz of spectrum assigned in the high-band. 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.

Figure 3: Amount of 5G spectrum assigned in international markets[38]



[38] Note: Due to the nature of spectrum assignments in the USA being regional, only the three big national operators were included: T-Mobile; AT&T and Verizon. The final spectrum amount was divided by the number of licenses to give a picture of how much spectrum is assigned in an average licensing area. For the EU, the data on spectrum assigned has been averaged across all EU27. Some individual countries may have more spectrum assigned for 5G, while some may have less or none.
Source: Data on international spectrum assignments is sourced from the Policy Tracker database.

A note on methodology:

China, South Korea, Japan

The source of data for China, South Korea and Japan is the PolicyTracker spectrum database. This is a comprehensive database of spectrum assignments.

All national spectrum licences were added up to find the total amount of spectrum that was assigned to mobile operators in each country. Only bands shown on the right side of the scoreboard were included in this. All of these bands are used to provide 5G services in their respective country.

USA

In the United States, licences are usually awarded regionally, a common example being the use of PEAs (partial economic areas) of which there are 406.[39] This makes it difficult to know how much spectrum mobile operators hold on a national level, as they hold different amounts of each band in each licence area.

Because of this, we have chosen to instead use the amount of spectrum that was initially made available to mobile operators by the country's spectrum regulator, the Federal Communications Commission (FCC) at auction. This data comes directly from the FCC and the list of awards can be found the table below.

In the 2.6 GHz band spectrum licenses are held by educational institutions. These are called Educational Broadband Service (EBS) licenses. T-Mobile leases a majority of these licences and has purchased some.[40] The total number of spectrum that T-mobile holds in these licences is unknown, however an estimate made by the FCC suggests the operator holds 155 MHz of spectrum in this band. [41] This is the estimate used in our data.

Regarding the CBRS auction, we have only counted the priority access licences (PAL) and the other spectrum made available is on an unlicensed basis.

Not all spectrum made available at these auctions will have been sold to operators. However, the amount of unsold spectrum licenses in these auctions is small. Furthermore, the amount of spectrum was cross-checked with the PolicyTracker spectrum database. This is a comprehensive database of spectrum assignments in over 100 countries.

Low-band spectrum	MHz	Source URL
600 MHz (Incentive auction)	70	https://auctiondata.fcc.gov/public/projects/1000

[39] https://www.fcc.gov/oet/maps/areas
[40] https://www.lightreading.com/5g/inside-the-messy-world-of-t-mobiles-midband-5g-spectrum-licenses/d/d-id/774745
[41] https://www.fcc.gov/reports-research/reports/consolidated-communications-marketplace-reports/CMR-2020

Mid-band spectrum	MHz	Source URL	Comments
CBRS (PAL licences)	70	https://www.fcc.gov/auction/105/factsheet	70 MHz was awarded as priority licences. However, operators may be able to use the entire CBRS range of 100 MHz in some circumstances.
3.45 - 3.55 GHz (Auction 110)	100	https://www.fcc.gov/auction/110/factsheet	
3.7 - 4.2 GHz (Auction 107) (C-band auction)	280	https://www.fcc.gov/auction/107/factsheet	
2.6 GHz (T-Mobile's holdings of education spectrum)	155	https://www.fcc.gov/reports-research/reports/consolidated-communications-marketplace-reports/CMR-2020	FCC estimate from 2020 marketplace report (p.24)
Total	605		

High-band spectrum	MHz	Source URL
28 GHz (Auction 101)	850	https://www.fcc.gov/auction/101/factsheet
24 GHz (Auction 102)	700	https://www.fcc.gov/auction/102/factsheet
37 GHz and 39 GHz (Auction 103)	2400	https://www.fcc.gov/auction/103/factsheet
47 GHz (Auction 103)	1000	https://www.fcc.gov/auction/103/factsheet
Total	4950	

European Union

Because spectrum assignments differ amongst EU Member States, the number used in the scoreboard is an average. To calculate this average, the total amount of spectrum assigned in each of the 5G pioneer bands for each country was added up and then divided by the total number of Member States.

Spectrum assignment data was retrieved from the 5G readiness indicator which is produced for the Digital Economy and Society Index (DESI).

This data represents an average but the situation in individual countries may be very different. To see a full breakdown of spectrum assignments in the EU, please refer to section 5.4.

5G verticals and trials

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.

5G verticals in the EU

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

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

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

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

5G vertical spectrum: Is there a need for dedicated spectrum?

The licensing model (or model***s***) needed for 5G verticals is on an ongoing debate in the spectrum management world. 5G verticals can either use spectrum already assigned to mobile operators, or they can rely on dedicated spectrum licences issued by governments.

Some stakeholders argue in favour of dedicated spectrum, but there are also arguments against this. The mobile industry association, the GSMA, has warned[42] 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.

Despite this ongoing debate, an increasing number of countries are adopting a local licensing model that use dedicated spectrum for 5G verticals. Germany was the first country to decide to reserve the 3700 – 3800 MHz band for verticals. This may be because of the potential benefits for industrial companies, which account for about 20% of the country's GDP.[43]

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

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

Belgium and the Netherlands proposed a similar approach to Germany. Sweden has also adopted a local licensing model in the 3.6 GHz and 26 GHz bands.[44]

Although many European countries have adopted the approach of dedicating spectrum for verticals, the exact portions of spectrum used for these licences varies across Europe. This can cause issues when it comes to harmonisation efforts or standardising equipment. However, the 3.8 - 4.2 GHz band is emerging as a potential solution for this problem. The band has the potential to become the de-facto vertical band for Europe.

The UK was the first European country to release[45] the band in 2019 exclusively for local private and shared networks. Most recently, France followed in the UK's footsteps by opening up the 3.8 - 4.0 GHz band for 5G verticals licences.[46]

The European Radio Spectrum Policy Group (RSPG) has previously published a consultation recommending member states to explore the use of the 3.8 – 4.2 GHz band for 5G verticals.[47] In 2021, the European Union's Radio Spectrum Committee (RSC) mandated CEPT to develop harmonised technical conditions for the shared use of 3.8—4.2 GHz, however the work on these efforts is still ongoing within the technical body.

[42] https://www.gsma.com/spectrum/resources/mobile-networks-for-verticals/
[43] https://www.statista.com/statistics/295519/germany-share-of-economic-sectors-in-gross-domestic-product/
[44] https://pts.se/sv/nyheter/radio/2021/pts-oppnar-for-tilldelning-av-lokala-tillstand-i-37-ghz--och-26-ghz-banden/
[45] https://www.policytracker.com/ofcom-makes-3-8-4-2-ghz-available-for-private-networks/
[46] https://www.policytracker.com/france-seeks-to-expand-industrial-5g/
[47] https://www.policytracker.com/3-8-4-2-ghz-gains-momentum-after-rspg-backing/

In Asia, the notion of 5G private networks has some traction. In Japan[48] a significant number of major companies have already acquired a spectrum licence.[49] 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.[50]

In the US, the FCC is hoping that it's three tier CBRS (Citizens Broadband Radio Service) approach 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.[51]

Nevertheless, internationally the vast majority of the countries have not yet reserved frequencies for enterprises. In these markets, verticals will have to rely either on unlicensed spectrum, services provided by MNOs 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.

Trends related to vertical trials

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 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. Work on Release 17, which will also introduce new features for 5G verticals, only recently concluded in March 2022. 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 covid-19 pandemic may have also contributed to delays.

5G verticals appear to be particularly developed in ports and has been extensively tested in several countries. 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.[52]
- **Belgium**: Proximus and the Port of Antwerp have announced a 6-month trial of a private 5G network.[53]
- **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.[54]

[48] https://www.policytracker.com/japan-awards-its-first-commercial-licences-for-local-5g/
[49] https://www.policytracker.com/japan-awards-its-first-commercial-licences-for-local-5g/
[50] https://www.policytracker.com/south-korea-to-allocate-local-5g-spectrum-for-the-first-time/
[51] https://www.fiercewireless.com/private-wireless/john-deere-foresees-private-5g-at-its-factories-worldwide
[52] https://www.telekom.com/en/media/media-information/archive/port-of-hamburg-is-ready-for-5g-574536
[53] 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
[54] https://citymesh.com/en/news/port-of-zeebrugge-accelerates-innovation-by-investing-in-a-5g-network

- **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.[55]
- **Spain**: Telefónica and APM Terminals have trialled 5G at the port of Barcelona. This test included connecting cranes, vehicles and people.[56]

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.[57]
- **Norway**: Ericsson, Telia and the Norwegian University of Science and Technology have carried out a demonstration of a 5G autonomous ferry.[58]
- **Germany:** Sony and Vodafone have conducted remote 5G car trials in Aldenhoven, Germany.[59]

Other notable recently announced 5G verticals include:

- Germany: Volkswagen and Nokia trial private 5G network at manufacturing plant.[60]
- Finland: Nokia to build private 5G network in Finnish goldmine.[61]
- Germany: Vodafone Germany launches standalone 5G network at a University Hospital in Kiel.[62]

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 (**Error! Reference source not found.**), 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[63] and Vodafone[64] Germany's recent announcement of 5G plans for the BMW iX car. This integration allows drivers to use 5G connectivity in their cars.

5G private networks

Deployment of 5G private networks is growing across EU countries. These networks 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 Observatory has produced a non-exhaustive list of private 5G networks which is based on research of publicly available information. The Observatory team endeavour to obtain as much information on

[55] https://www.ericsson.com/en/cases/2017/5g-telia-tallink

[56] 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

[57] 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/

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

[59] https://5gobservatory.eu/sony-and-vodafone-conduct-remote-5g-car-trial-in-germany/

[60] https://5gobservatory.eu/volkswagen-and-nokia-trial-private-5g-network-at-manufacturing-plant/

[61] https://5gobservatory.eu/nokia-to-build-private-5g-network-in-finnish-goldmine/

[62] https://5gobservatory.eu/vodafone-germany-launches-5g-standalone-network-at-university-hospital/

[63] 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

[64] 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

published private 5G network deployments as possible. The analysis from last quarterly report can be found on the website here

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

There have been a number of major procurements by large operators across EU countries in recent months. The table of which vendors have won contracts for the provision of 5G network builds across Member State countries is available to search and extract on the 5G Observatory website.

EMF developments related to 5G policy goals

An EMF explainer is available online here.

Key highlights:

- Application of EMF limits remains inconsistent across Member States
- No significant updates in the past three months

The 2018 Electronic Communications Code recommends setting limits on exposure to electromagnetic fields (EMF) in line with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines, which are 50 times less than the level where there has been substantiated evidence of health damage. However, these limits are not binding on Member States and there is inconsistency in how they are applied and this can restrict the economic and social benefits of including 5G. Current EMF policies in the Member States are shown in the table below.

Table 8: .Current EMF policies in the Member States

Countries	ICNIRP limits used?	Details
Austria	Yes	
Belgium	No	More restrictive than ICNIRP. Each region has its own limits, but those in Brussels were relaxed in August 2021
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

Countries	ICNIRP limits used?	Details
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	
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

5G corridors

Highlights (past 3 months):

- No significant updates in the past three months

The analysis from the last quarterly report can be found here.

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. The full paper providing an overview of the toolbox as well as measures already taken by Member States can be found here.

Below are some highlights summarising the latest developments.

Since the publication of the last report, there have been no new developments in the implementation of 5G security toolbox amongst Member States.

However, in the mobile industry, there is an increased focus on developing Open RAN technology. If deployed, Open RAN will create a more diverse telecoms supplier market. In March, Vodafone announced it would target to use Open RAN in 30% of its European sites by 2030.[65]

65 https://5gobservatory.eu/vodafone-targets-open-ran-in-30-of-its-european-network-sites-by-2030/

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

Sustainability is another key topic accompanying 5G development. The full paper providing an 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 can be found in here.

Below are some highlights summarising developments since the last QR publication:

- New European Commission the European Parliament Pilot project on **measuring the environmental impact of real-life digital solutions**: the European Green Digital Coalition (EGDC) formed by 26 CEOs of companies signing a Declaration to support the Green and Digital Transformation of the EU, together with industry associations and partnering organisations, will be working on developing science-based methods to estimate the net environmental impact of real-life digital solutions. The EP Pilot project will create recommendations for green digital transformation across and promote a widespread take-up by industry players, including SMEs. The Pilot Project will take place over two years and aims at delivering the first results already in 2022.
- In France, ARCEP conducted a **study on mobile networks', including 5G, environmental footprint,** to conclude that "energy efficiency gains achieved from 5G deployment will begin in 2023 and be clear by 2028 in the most densely populated areas". Nevertheless, improvements in energy consumption in sparsely populated where traffic density is lower, virtually non-existent will not be seen until 2025 at the earliest, and by 2028 at the latest.
- Finally, as ETNO expects the roll-out of optical networks and 5G will continue to improve the energy efficiency of the telecom sector, its latest report provides an update on the operators' performance in terms of CO2e emissions and overall energy consumption.

Annex II: Detailed country situation

Austria

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	1,252[66]	
	- Network performance: speed	83.57 Mbps[67]	
	- Current usage of 5G pioneer bands	65.83%[68]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	76.8% (overall) 36.3% (rural)[69]	
	- 5G corridors	Brenner Corridor IT-AT-DE[70]	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	**Implemented**[71]	
	- 5G verticals (trials & initiatives)	None identified	
Other (indirectly relevant) targets[72]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	53%[73]	

[66] Source: EC
[67] Overall mobile data speed 03/22. Source: Ookla
[68] 1000 MHz temporary licences in 26 GHz band to academia in order to enable 26 GHz for a 5G launch. The 10 MHz as guard band in 3.6 GHz band.
Source: EC.
[69] Source: DESI (2021 data)
[70] https://5gcarmen.eu/
[71] Regional licences in 3400-3800 MHz
[72] 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.
[73] €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

Belgium

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	256[74]	
	- Network performance: speed	82.78 Mbps[75]	
	- Current usage of 5G pioneer bands	3.33%[76]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	4.25% (overall) 0% (rural)[77]	
	- 5G corridors	Antwerp-Rotterdam-North Sea (Vlissingen) BE-NL[78]	
"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[79]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	27%[80]	

[74] Source: EC.
[75] Overall mobile data speed 03/22. Source: Ookla
[76] 150MHz in 3.6GHz temporary licences to enable 5G launch.
Source: EC.
[77] Source: DESI (2021 data)
[78] https://5g-ppp.eu/5g-blueprint/
[79] 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.
[80] € 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

Bulgaria

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	257[81]	
	- Network performance: speed	187.71 Mbps[82]	
	- Current usage of 5G pioneer bands	25%[83]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	40.1% (overall) 8.55% (rural)[84]	
	- 5G corridors	Thessaloniki, Sofia-Belgrade EL-BG-RS[85]	
"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[86]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[87]	

[81] Source: EC.
[82] Overall mobile data speed 03/22. Source: Ookla
[83] Note:
- In 700 MHz band there is no interest in acquiring spectrum during 2020. A new public consultation is planned in 2022. The probable year announced by the operators for the acquisition of spectrum is 2023.
- In 3.4-3.8 GHz band in 2021 three operators aqured licences, total 3x100 MHz. In band 3.4-3.6 GHz there are free 70 MHz, 30 MHz are used for national security purposes. In 2023 a new public consultation is planned.
- In 26 GHz band available spectrum is 2.578 GHz. Consultations held at the end of 2020 - beginning of 2021, declared fundamental interest. There is use of fixed networks (point-to-point and FWA), envisaged managed shared use of fixed and terrestrial networks. In 2022, a new public consultation is planned.
Source: EC.
[84] Source: DESI (2021 data)
[85] https://digital-strategy.ec.europa.eu/en/news/new-5g-cross-border-corridor-connected-and-automated-mobility-announced-digital-assembly-2018
[86] 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.
[87] Source: https://www.nextgeneration.bg/upload/36/Bulgaria_Recovery_and_Resilience_Plan_ENG.pdf

Croatia

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	449[88]	
	- Network performance: speed	140.53 Mbps[89]	
	- Current usage of 5G pioneer bands	100%[90]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	33.8% (overall) 9.26% (rural)[91]	
	- 5G corridors	No agreement/project identified	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Proposed[92]	
	- 5G verticals (trials & initiatives)	0 trials identified	
Other (indirectly relevant) targets[93]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	20%[94]	

[88] Source: EC.
[89] Overall mobile data speed 03/22. Source: Ookla
[90] In band 3.4-3.6 GHz 80 MHz is licensed for 5G to regional operators and 120 MHz to national operators.
Source: EC.
[91] Source: DESI (2021 data)
[92] Regional licences in 3410-3800 MHz
[93] 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.
[94] € 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

Cyprus

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	873[95]	
	- Network performance: speed	173.06 Mbps[96]	
	- Current usage of 5G pioneer bands	66.67%[97]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	75% (overall) 32.2% (rural)[98]	
	- 5G corridors	No agreement/project identified	
"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[99]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	23%[100]	

[95] Source: EC.
[96] Overall mobile data speed 03/22. Source: Ookla
[97] Source: EC.
[98] Source: DESI (2021 data)
[99] 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.
[100] € 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.

Czechia

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	2,674[101]	
	- Network performance: speed	72.74 Mbps[102]	
	- Current usage of 5G pioneer bands	66.67%[103]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	49.4% (overall) 43.3% (rural)[104]	
	- 5G corridors	Czech-Bavarian 5G corridor[105]	
"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[106]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[107]	

[101] Source: EC.
[102] Overall mobile data speed 03/22. Source: Ookla
[103] 1000 MHz in 26GHz band is reserved for experimental individual authorisation.
Source: EC.
[104] Source: DESI (2021 data)
[105] 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/
[106] 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.
[107] € 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

Denmark

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	3,146[108]	
	- Network performance: speed	164.26 Mbps[109]	
	- Current usage of 5G pioneer bands	99.17%[110]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	98.8% (overall) 98.0% (rural)[111]	
	- 5G corridors	Nordic Way2 NO-SE-FI-DK[112]	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Proposed[113]	
	- 5G verticals (trials &) initiatives	0 trials identified	
Other (indirectly relevant) targets[114]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	25%[115]	

[108] Source: EC.
[109] Overall mobile data speed 03/22. Source: Ookla
[110] The 10 MHz as guard band in 3.6 GHz band.
Source: EC.
[111] Source: DESI (2021 data)
[112] https://www.nordicway.net/
[113] 3740–3800 MHz under investigation
[114] 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.
[115] € 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

Estonia

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	0[116]	
	- Network performance: speed	77.79 Mbps[117]	
	- Current usage of 5G pioneer bands	0%	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	18.3% (overall) 1.5% (rural)[118]	
	- 5G corridors	5G-Routes (CAM, Rail, maritime) EE-LT-LV[119]	
"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[120]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[121]	

Finland

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	5,000[122]	
	- Network performance: speed	108.65 Mbps[123]	

[116] Source: EC.
[117] Overall mobile data speed 03/22. Source: Ookla
[118] Source: DESI (2021 data)
[119] https://www.5g-routes.eu/
[120] 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.
[121] € 204 million (Digitalising companies; Digitalising public administration; Increasing connectivity).
Source: factsheet-estonia_en.pdf (europa.eu)
[122] Source: EC.
[123] Overall mobile data speed 03/22. Source: Ookla

	- Current usage of 5G pioneer bands	99.17%[124]	
	- 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.[125]	
	- Population coverage	71.6% (overall) 18.9% (rural)[126]	
	- 5G corridors	- Nordic Way2 NO-SE-FI-DK [127] - E8 "Aurora Borealis" NO-FI	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Implemented[128]	
	- 5G verticals (trials &) initiatives	4 trials identified	
Other (indirectly relevant) targets[129]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	27%[130]	

France

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	26,138[131]	
	- Network performance: speed	112.07 Mbps[132]	
	- Current usage of 5G pioneer bands	59.17%[133]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	

[124] The 10 MHz as guard band in 3.6 GHz band. The 26 GHz area has been fully assigned, in total 3250 MHz; 24,25-25,1 GHz for local networks and 25,1-27,5 GHz for operators.
Source: EC.
[125] Fast 5G already available to more than 1.8 million Finnish households | Traficom
[126] Source: DESI (2021 data)
[127] https://www.nordicway.net/
[128] 24.25–25.1 GHz
[129] 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.
[130] € 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)
[131] Source: EC.
[132] Overall mobile data speed 03/22. Source: Ookla
[133] Source: EC.

	- Population coverage	74.4% (overall) 48.2% (rural)[134]	
	- 5G corridors	Barcelona-Perpignan, Santander-Biarritz ES-FR [135]	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Implemented[136]	
	- 5G verticals (trials &) initiatives	3 trials identified	
Other (indirectly relevant) targets[137]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[138]	

Germany

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	50,216[139]	
	- Network performance: speed	97.34 Mbps[140]	
	- Current usage of 5G pioneer bands	100%[141]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	86.5% (overall) 49.4% (rural)[142]	
	- 5G corridors	- Brenner Corridor IT-AT-DE[143] - Metz-Merzig-Luxembourg FR-DE-LU[144] - CZ-Bavaria: Prague-Munich	

[134] Source: DESI (2021 data)
[135] 5GMED – Future mobility in the Mediterranean Cross Border Corridor
[136] 2575–2615 MHz
[137] 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.
[138] € 1 billion (digitalisation of companies; digitalisation of schools; digitalisation of public administration). Source: france-recovery-resilience-factsheet_en.pdf (europa.eu)
[139] Source: EC.
[140] Overall mobile data speed 03/22. Source: Ookla
[141] Source: EC.
[142] Source: DESI (2021 data)
[143] Home page - 5G CARMEN
[144] 5GCroCo

"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Implemented[145]	
	- 5G verticals (trials & initiatives)	17 trials identified	
Other (indirectly relevant) targets[146]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	52%[147]	

Greece

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	3,448[148]	
	- Network performance: speed	114.71 Mbps[149]	
	- Current usage of 5G pioneer bands	99.17%[150]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	66.1% (overall) 17.3% (rural)[151]	
	- 5G corridors	Thessaloniki, Sofia-Belgrade EL-BG-RS	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	proposed[152]	
	- 5G verticals (trials & initiatives)	2 trials identified	

[145] 3700–3800 MHz & 26 GHz
[146] 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.
[147] € 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)
[148] Source: EC.
[149] Overall mobile data speed 03/22. Source: Ookla
[150] 3400-3410MHz reserved for 5G pilot, testing & research applications.
Source: EC.
[151] Source: DESI (2021 data)
[152] Greece has reserved spectrum in 733-736 MHz and 788-791 MHz, 3400-3410 MHz, as well as 200 MHz from the higher 26 GHz band.

Other (indirectly relevant) targets[153]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	23.3%[154]	

Hungary

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	1,331[155]	
	- Network performance: speed	79.94 Mbps[156]	
	- Current usage of 5G pioneer bands	60.28%[157]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	17.6% (overall) 7.03% (rural)[158]	
	- 5G corridors	None identified	
"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[159]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not approved yet	

[153] 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.
[154] € 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)
[155] Source: EC.
[156] Overall mobile data speed 03/22. Source: Ookla
[157] The 10 MHz as guard band in 3.6 GHz band. Regarding 26 GHz spectrum band, NMHH has already conducted 2 public consultations and no need for this band was indicated from the operators. NMHH held the 3rd public consultation on 22nd March 2022 about the use of this spectrum band. The analyses of the conclusion of the 3rd public consultation is underway.
Source: EC.
[158] Source: DESI (2021 data)
[159] 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.

Ireland

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	1,183[160]	
	- Network performance: speed	75.42 Mbps[161]	
	- Current usage of 5G pioneer bands	29.17%[162]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	72.1% (overall) 36.2% (rural)[163]	
	- 5G corridors	None identified	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	None	
	- 5G verticals (trials &) initiatives	None identified	
Other (indirectly relevant) targets[164]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[165]	

[160] Source: EC.
[161] Overall mobile data speed 03/22. Source: Ookla
[162] The 10 MHz as guard band in 3.6 GHz band. Multi-band spectrum award which includes the 700 MHz band is under legal appeal. Recent report indicates no user cases for the 26 GHz band and no justification for its award. 60 MHz band in 700 MHz band issued to three MNO's under emergency COVID legislation - full technology and service neutrality.
Source: EC.
[163] Source: DESI (2021 data)
[164] 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.
[165] € 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)

Italy

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	0[166]	
	- Network performance: speed	62.72 Mbps[167]	
	- Current usage of 5G pioneer bands	60%[168]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	99.7% (overall) 99.8% (rural)[169]	
	- 5G corridors	Brenner Corridor IT-AT-DE[170]	
"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[171]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	25%[172]	

[166] No data available.
Source: EC.
[167] Overall mobile data speed 03/22. Source: Ookla
[168] Source: EC.
[169] Source: DESI (2021 data)
[170] Home page - 5G CARMEN
[171] 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.
[172] € 26.1 billion (development of ultra-fast and 5G networks; digitalisation of businesses; digitalisation of the public administration).
Source: italy-recovery-resilience-factsheet_en.pdf (europa.eu)

Latvia

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	15,796[173]	
	- Network performance: speed	64.63 Mbps[174]	
	- Current usage of 5G pioneer bands	62.50%[175]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% (rural)[176]	
	- 5G corridors	5G-Routes (CAM, Rail, maritime) EE-LT-LV[177]	
"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[178]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[179]	

[173] Source: EC.
[174] Overall mobile data speed 03/22. Source: Ookla
[175] LV has recently released 50 MHz in 3.6-3.8 GHz band, so only 350 MHz remain awarded under 5G conditions. 112 MHz in 26GHz band has been assigned to Fixed Links.
Source: EC.
[176] Source: DESI (2021 data)
[177] Home - 5g routes project (5g-routes.eu)
[178] 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.
[179] € 232.5 million: businesses digitalisation; digital upskilling; 5G deployment.
Source: latvia-recovery-resilience-factsheet_en.pdf (europa.eu)

Lithuania

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	417[180]	
	- Network performance: speed	74.82 Mbps[181]	
	- Current usage of 5G pioneer bands	5.42%[182]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	33.3% (overall) 0.8% (rural)[183]	
	- 5G corridors	- 5G-Routes (CAM, Rail, maritime) EE-LT-LV[184] - LT-PL Via Baltica Kaunas-Warsaw	
"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[185]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[186]	

[180] Source: EC.
[181] Overall mobile data speed 03/22. Source: Ookla
[182] 100 MHz in 3.6-3.8 GHz band and 2x10 MHz in 700 MHz band to test 5G technology, temporary licence 65 MHz within the band 3.6-3.8 GHz has been assigned for one operator under technology neutral licence and partly used for 5G as well. Spectrum auctions in the 700 MHz and 3.4-3.7 GHz will take place during the Q2 and Q3 of 2022.
Source: EC.
[183] Source: DESI (2021 data)
[184] Home - 5g routes project (5g-routes.eu)
[185] 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.
[186] € 307 million: tailored technology for the Lithuanian language; customer-oriented services; 5G networks.
Source: com-2021-386-lithuania_factsheet_en.pdf (europa.eu)

Luxembourg

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	157[187]	
	- Network performance: speed	139.19 Mbps[188]	
	- Current usage of 5G pioneer bands	60.83%[189]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	12.7% (overall) 6.67% (rural)[190]	
	- 5G corridors	Metz-Merzig-Luxembourg FR-DE-LU[191]	
"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[192]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	32%[193]	

[187] Source: EC.
[188] Overall mobile data speed 03/22. Source: Ookla
[189] Source: EC.
[190] Source: DESI (2021 data)
[191] 5GCroCo
[192] 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.
[193] € 23.8 million: secure communications; digital services for public; digitise healthcare.
Source: luxembourg-recovery-resilience-factsheet_en.pdf (europa.eu)

Malta

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	490[194]	
	- Network performance: speed	83.77 Mbps[195]	
	- Current usage of 5G pioneer bands	25%[196]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	20% (overall) 0% (rural)[197]	
	- 5G corridors	None identified	
"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[198]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	26%[199]	

[194] Source: EC.
[195] Overall mobile data speed 03/22. Source: Ookla
[196] The MCA has assigned three spectrum licences in the 3.6GHz 5G pioneer band following an expression of interest in such spectrum by the MNOs currently operating in Malta. Malta has currently issued a trial licence in the 700 MHz band to one of the MNOs for test and trial purposes.
Source: EC.
[197] Source: DESI (2021 data)
[198] 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.
[199] € 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)

Netherlands

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	11,227[200]	
	- Network performance: speed	124.76 Mbps[201]	
	- Current usage of 5G pioneer bands	33.33%[202]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	97% (overall) 96.8% (rural)[203]	
	- 5G corridors	Antwerp-Rotterdam-North Sea (Vlissingen) BE-NL[204]	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Proposed[205]	
	- 5G verticals (trials & initiatives)	4 trials identified	
Other (indirectly relevant) targets[206]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not submitted yet	

Poland

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	13,293[207]	
	- Network performance: speed	57.86 Mbps[208]	

[200] Source: EC.
[201] Overall mobile data speed 03/22. Source: Ookla
[202] Source: EC.
[203] Source: DESI (2021 data)
[204] 5G-BLUEPRINT ‹ 5G-PPP
[205] Plans to set aside 3750–3800 MHz
[206] 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.
[207] Source: EC.
[208] Overall mobile data speed 03/22. Source: Ookla

	- Current usage of 5G pioneer bands	0%[209]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	34.2% (overall) 13.5% (rural)[210]	
	- 5G corridors	LT-PL Via Baltica Kaunas-Warsaw	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Proposed[211]	
	- 5G verticals (trials & initiatives)	0 trials identified	
Other (indirectly relevant) targets[212]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not submitted yet	

Portugal

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	145[213]	
	- Network performance: speed	134.74 Mbps[214]	
	- Current usage of 5G pioneer bands	61.11%[215]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	0% (overall) 0% (rural)[216]	

[209] Source: EC.
[210] Source: DESI (2021 data)
[211] Considering allocation in 3.5 GHz
[212] 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.
[213] Source: EC.
[214] Overall mobile data speed 03/22. Source: Ookla
[215] Updated with the recent multiband auction (700 MHz / 900 MHz / 1800 MHz / 2.1 GHz / 2.6 GHz / 3.6 GHz). Source: EC.
[216] Source: DESI (2021 data)

	- 5G corridors	Porto-Vigo, Evora-Merida PT-ES[217]	
"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[218]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	22%[219]	

Romania

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	1,207[220]	
	- Network performance: speed	72.87 Mbps[221]	
	- Current usage of 5G pioneer bands	21.67%[222]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	24.9% (overall) 2.04% (rural)[223]	
	- 5G corridors	None identified	
"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	

[217] 5G-MOBIX

[218] 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.

[219] € 1.5 billion: vocational education and training institutions; digital health transition; digital transition of businesses. Source: portugal-recovery-resilience-factsheet_en.pdf (europa.eu)

[220] Source: EC.

[221] Overall mobile data speed 03/22. Source: Ookla

[222] ANCOM conducted in 2021 a multiband auction that also included the 90 MHz still free in the 3.4-3.6 GHz band. Only 5 MHz were awarded with this occasion, to a new entrant in the band.
Source: EC.

[223] Source: DESI (2021 data)

Other (indirectly relevant) targets[224]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[225]	

Slovakia

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	351[226]	
	- Network performance: speed	59.51 Mbps[227]	
	- Current usage of 5G pioneer bands	66.67%[228]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	13.8% (overall) 2.43% (rural)[229]	
	- 5G corridors	None indentified	
"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[230]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[231]	

[224] 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.
[225] € 2.8 billion: digitalisation of public administration; digitalisation of health; digitalisation of education. Source: factsheet-romania_en.pdf (europa.eu)
[226] Source: EC.
[227] Overall mobile data speed 03/22. Source: Ookla
[228] Source: EC.
[229] Source: DESI (2021 data)
[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] € 466 million: better services for citizens and businesses; digital infrastructure in schools; digitalising businesses. Source: slovakia-recovery-resilience-factsheet_en.pdf (europa.eu)

Slovenia

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	492[232]	
	- Network performance: speed	87.43 Mbps[233]	
	- Current usage of 5G pioneer bands	98.33%[234]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	36.6% (overall) 2.83% (rural)[235]	
	- 5G corridors	None identified	
"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[236]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	21%[237]	

[232] Source: EC.
[233] Overall mobile data speed 03/22. Source: Ookla
[234] The lower 20 MHz as guard band in 3.6 GHz planned for local use by auction in 2022/2023.
Source: EC.
[235] Source: DESI (2021 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] € 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)

Spain

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	7,510[238]	
	- Network performance: speed	66.33 Mbps[239]	
	- Current usage of 5G pioneer bands	65%[240]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	58.9% (overall) 24.8% (rural)[241]	
	- 5G corridors	Barcelona-Perpignan, Santander-Biarritz ES-FR[242]	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Proposed [243]	
	- 5G verticals (trials &) initiatives	16 trials identified	
Other (indirectly relevant) targets[244]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	28%[245]	

[238] Source: EC.
[239] Overall mobile data speed 03/22. Source: Ookla
[240] A Public Consultation on the existing demand and on the management and exploitation model of the 26 GHz frequency band (24.25 to 27.50 GHz) was launched in December 2021 and lasted till the end of January 2022. The report about the main information received from the contributions to this public consultation will be published in April. Currently, the band is available for tests applications having issued some. During 2022 it is foreseen to hold an auction for the band.
Source: EC.
[241] Source: DESI (2021 data)
[242] 5GMED – Future mobility in the Mediterranean Cross Border Corridor
[243] Reports for industry allocation in 26 GHz
[244] 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.
[245] € 9.8 billion: digital skills training; digitalisation of public administration; digitalisation of business. Source: spain-recovery-resilience-factsheet_en.pdf (europa.eu)

Sweden

Target	Indicator(s)	Performance	On Track
-all populated areas are covered by 5G by 2030	- Number of base stations deployed (progress of deployments)	0[246]	
	- Network performance: speed	159.00 Mbps[247]	
	- Current usage of 5G pioneer bands	80.56%[248]	
	- Number of km served across main transport paths (progress of deployments)	No data reported	
	- Population coverage	17.7% (overall) 0.48% (rural)[249]	
	- 5G corridors	Nordic Way2 NO-SE-FI-DK[250]	
"digital technologies including 5G"…."at the core of new products, new manufacturing processes and new business models" by 2030	- specific provisions for verticals	Implemented [251]	
	- 5G verticals (trials & initiatives)	3 trials identified	
Other (indirectly relevant) targets[252]	- Member States spending on to the digital priority (%Recovery and Resilience Plans). -	Recovery and Resilience Plan not approved yet	

[246] Source: EC.
[247] Overall mobile data speed 03/22. Source: Ookla
[248] Part of 3.4-3.8 GHz band auctioned on 19/1/21, 40 MHz in 3,76-3,8 GHz and 850 MHz in 26 GHz band, released for local licences on 22/11/21.
Source: EC.
[249] Source: DESI (2021 data)
[250] Nordicway2
[251] 3720–3800 MHz
[252] 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.