Key findings of a study conducted by Analysys Mason on behalf of Arcep on the evolution of uses of wireless telecommunications networks and on the dimensioning of those networks

1 Introduction and objectives of the study

As part of its radio spectrum resources management responsibilities, Arcep considers it necessary to be able to map out future scenarios for the evolution of uses that could affect wireless network dimensioning requirements, particularly in terms of allocation of new spectrum bands.

Several harmonised spectrum bands are available or likely to become available for the deployment of mobile networks in metropolitan France:

- in the short/medium term, notably the 3410 – 3490 MHz and 1427 – 1517 MHz bands (the latter referred to as the "1.4 GHz band") bands, the upper 6 GHz band (6425 – 7125 MHz), the 26 GHz band, or
- in the longer term, the 42 GHz and the 470 – 694 MHz bands.

It was against this backdrop that Arcep commissioned a study to obtain forward-looking elements on the evolution of uses of wireless networks, and perform simulations on wireless telecommunications network dimensioning requirements according to multiple scenarios and assumptions. The objective of the study is to inform Arcep about:

- the risks of wireless network congestion according to different scenarios for the evolution of uses on these networks;
- the potential benefits of using the upper 6 GHz band (i.e. frequencies from 6425 MHz to 7125 MHz), depending on whether it would be used by Wi-Fi or cellular networks.

This document provides a summary of the study's deliverables and its key findings by presenting:

- a description of the methodological approach taken by the consultant to assess demand projections and the different wireless network deployment scenarios;
- the study's main results in terms of the incremental number of mobile sites needed to satisfy demand according to the network deployment assumptions, along with an estimate of the associated carbon footprint;
- the study's key findings, conclusions and its limitations.

This document is a summary of the analyses conducted by Analysys Mason. Its conclusions do not prejudice the Authority's future radio spectrum management policy directions or decisions. The objective of making this document publicly available is to contribute to a deeper understanding of the effects of the evolution of uses of wireless networks, and the role given to spectrum use as a result – as part of an exploratory and forward-looking exercise, based on the data available to date and with well-defined assumptions.

To obtain a critical analysis of the study's findings, the Authority was supported throughout the conduct of the study by an advisory committee, acting as advisors and reviewers, composed of four academic experts[1]. The Authority is also publishing this committee's review of the study and its findings.

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[1] Clément Marquet (Research fellow at the Centre de Sociologie de l'Innovation, Mines Paris – PSL), James F. Kurose (Professor at the University of Massachusetts (E.U) and visiting researcher at the Université Pierre and Marie Curie (Paris VI – Sorbonne)), Jean-Samuel Beuscart (Professor at Sciences Po Medialab) and Marios Kountouris (Professor at EURECOM, France).

2 Methodological approach

The study involved three phases:

- **Phase 1:** simulate the volume of traffic according to multiple scenarios for the evolution of usees and demand for connectivity on wireless networks, broken down into different use cases (web, streaming, gaming, XR…) ;
- **Phase 2:** model different network deployment scenarios (cellular, Wi-Fi, satellite) to satisfy the evolution of demand, based on different assumptions (e.g. available spectrum resources)
- **Phase 3:** assess the carbon footprint associated with the different network deployment scenarios, and demand evolution scenarios.

2.1 Phase 1: Evolution of demand

2.1.1 Scope of uses considered in the study and their projections

a) Categorisation of uses considered in the study

The model focuses on mobile internet service uses, which are the ones that generate the most traffic and create the highest demands in terms of network capacity and performance.

Voice, SMS (i.e. texting) and simple IoT[2] traffic are excluded from the model as they do not influence dimensioning in the same way as the most demanding use cases.[3] Moreover, the impact of artificial intelligence (AI) is taken into consideration in each of the modelled use cases, without being considered a use case in itself (for instance, the use of an AI tool that generates text is considered as contributing to the traffic generated by the "Web browsing and file download" use case). A great deal of uncertainty nevertheless remains over AI's impact on each use case's traffic and the ratio between upstream and downstream traffic.

Table 1 below provides a snapshot of the wireless connectivity use cases included in the model, and their characteristics.

Table 1 – Snapshot of the use cases considered in the study [Source: Analysys Mason, 2025]

Use case category	Location	Network features required	Sample use cases
Web browsing and file download	Mainly indoor	• High bandwidth	• Typical data traffic use by consumers
Streaming (video, music, etc.)	Indoor and outdoor	• High bandwidth • Low latency	• Video streaming (e.g. Netflix) • Music streaming (e.g. Spotify)
Real-time communication on OTT applications [4]	Indoor and outdoor	• Low latency	• Video calling • Real time gaming
Augmented, extended and virtual reality (AR, XR and VR)	Indoor and outdoor	• High bandwidth • Low latency	• Gaming • Immersive experiences/operational support • Training/education

[2] I.e. Internet of Things (IoT) connections that generate very little traffic.

[3] Although simple IoT connections may be very numerous, each one's individual traffic is so small that the total traffic they generate has very little effect on network dimensioning.

[4] Use cases based on "5G NR New Calling" features (https://www.gsma.com/solutions-and-impact/technologies/networks/wp-content/uploads/2023/10/GSMA-Foundry-5G-New-Calling-Revolutionising-the-Communications-Services-Landscape.pdf) can be considered examples of real-time OTT communication.

Use case category	Location	Network features required	Sample use cases
			• Digital twins
Connected and autonomous vehicles	Outdoor	• Low latency • Ultra-reliable communication • High bandwidth at certain autonomy levels	• Use by individuals • Public transport • Emergency vehicles • Drones
Complex IoT, high-speed data analytics	Indoor and outdoor	• High bandwidth • Low latency • Ultra-reliable communication	• Smart grid and smart cities • Predictive maintenance/fault detection
Robotics/ machine teleoperation	Mainly indoor	• High bandwidth • Low latency • Ultra-reliable communication	• Remote maintenance • Automated processes

b) Review of historic data traffic and existing forecasts

Demand forecasts by use case were established based on a bibliographic study that identified useful data, notably from BIPT[5], Ericsson[6] and Sandvine[7].

c) Projections for each use case category

Forecasts by use case for each scenario were established based on estimating traffic by device and number of devices, which vary from scenario to scenario. Input data for these elements were drawn from existing literature insofar as possible; otherwise they are Analysys Mason estimates based on its expertise of the industry[8].

The forecast traffic volume for each use case is then broken down by geotype (i.e. geographical segmentation), from "large urban centres" to "rural with very dispersed housing", defined based on INSEE data[9], thereby creating the ability to obtain a localised distribution of demand for each year.

To assess wireless network dimensioning requirements, modelling was performed on traffic levels at the busiest time of day, rather than average traffic throughout the day. As network load varies at different times of day and for different users, Analysys Mason estimated traffic during peak traffic hour based on its expertise. The values of the parameters used can be found in Table 2.

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[5] https://www.bipt.be/operators/publication/bipt-council-communication-of-14-april-2020-on-the-report-of-capgemini-invent-of-march-2020-concerning-the-evolution-of-mobile-data-associated-with-licensed-spectrum-in-belgium-and-the-impact-of-the-presence-of-media

[6]https://www.ericsson.com/en/reports-and-papers/mobility-report/mobility-visualizer?f=8&ft=2&r=1&t=1,20&s=4&u=3&y=2023,2029&c=3

[7] https://www.sandvine.com/hubfs/Sandvine_Redesign_2019/Downloads/2024/GIPR/GIPR%202024.pdf

[8] Given that traffic forecasts were established in the second half of 2024, when this study was being carried out, these forecasts factor in data up to the end of 2023. The study calibrated the traffic being offloaded from cellular to Wi-Fi networks by use case location, so that in the "Median" demand scenario, and with mobile operators' current spectrum holdings (network scenario A), the number of new sites in 2025 falls within a range that is consistent with site deployments in previous years.

[9] https://www.insee.fr/fr/statistiques/6686472

Table 2 – Peak traffic time modelling parameters

Number of busy days per year	Traffic on busy days	Traffic in the busy hour
250	75% of annual traffic	6.18% of daily traffic

2.1.2 Demand evolution scenarios

Demand forecasts were then established by use case, and grouped into four traffic evolution scenarios:

- **"Restrained consumption" scenario:** Under this scenario, take-up for consumer use cases increases apace with the population, but per-user consumption levels remain constant. Advanced consumer use cases taper off over time, and industrial use cases stagnate at current levels.

- **"Median" scenario:** Under this scenario, the evolution of consumer and industrial use cases follows historic trends, with increased demand for traffic and more widespread take-up.

- **"Increased digitalisation" scenario:** Under this scenario, the adoption of basic use cases and per-device traffic growth rises beyond historic levels. Adoption of advanced use cases increases beyond historic levels, but per-device traffic follows historic trends.

- **"Disruptive uses" scenario:** Under this scenario, the adoption of basic use cases and per-device traffic growth rises beyond historic levels. Adoption of advanced use cases increases beyond historic levels.

It is left up to the reader to assess the likelihood of the demand scenarios.

Table 3 illustrates how the two main drivers (number of users/subscribers, traffic per user) determine the dynamics of the four demand evolution scenarios.

Table 3 – Illustration of use case evolution dynamics for each demand scenario ((+) growth driver, (-) declining driver, (≈) stable/slightly changing driver)

Use case category	**"Restrained consumption"**		**"Median"**		**"Increased digitalisation"**		**"Disruptive uses"**	
Growth driver	**Subs.**	**Traffic per sub.**	**Subs.**	**Traffic per sub.**	**Subs.**	**Traffic per sub.**	**Subs.**	**Traffic per sub.**
Web browsing and file download	+	≈	+	+	+	++	+	++
Streaming (video, music, etc.)	+	≈	+	+	+	++	+	++
Real-time communication on OTT apps	+	≈	+	+	+	++	+	++
Augmented, extended and virtual reality (AR, XR, VR)	-	≈	+	+	++	++	++	+++
Connected and autonomous vehicles	≈	≈	+	+	++	++	++	+++
Complex IoT, high-speed data analytics	≈	≈	+	+	+	++	++	++
Robotics/machine teleoperation	≈	≈	+	+	+	++	++	++

Figure 1 to Figure 4 illustrate the evolution of traffic by use case under each scenario.

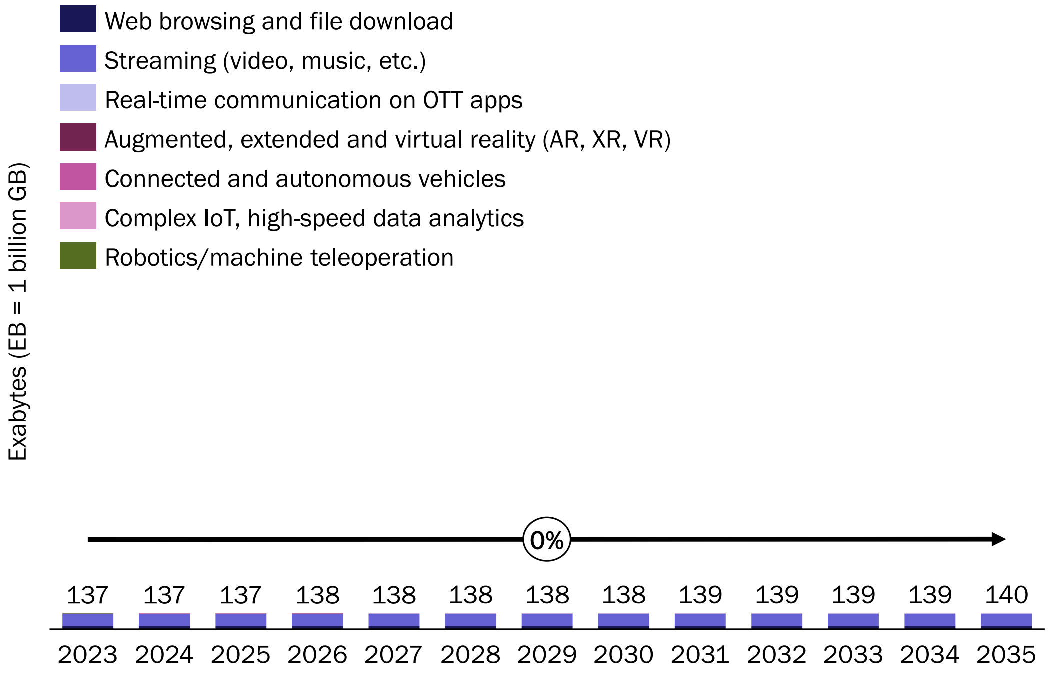

Figure 1 – Traffic by use cases under the "Restrained consumption" scenario [Source: Analysys Mason, 2025]

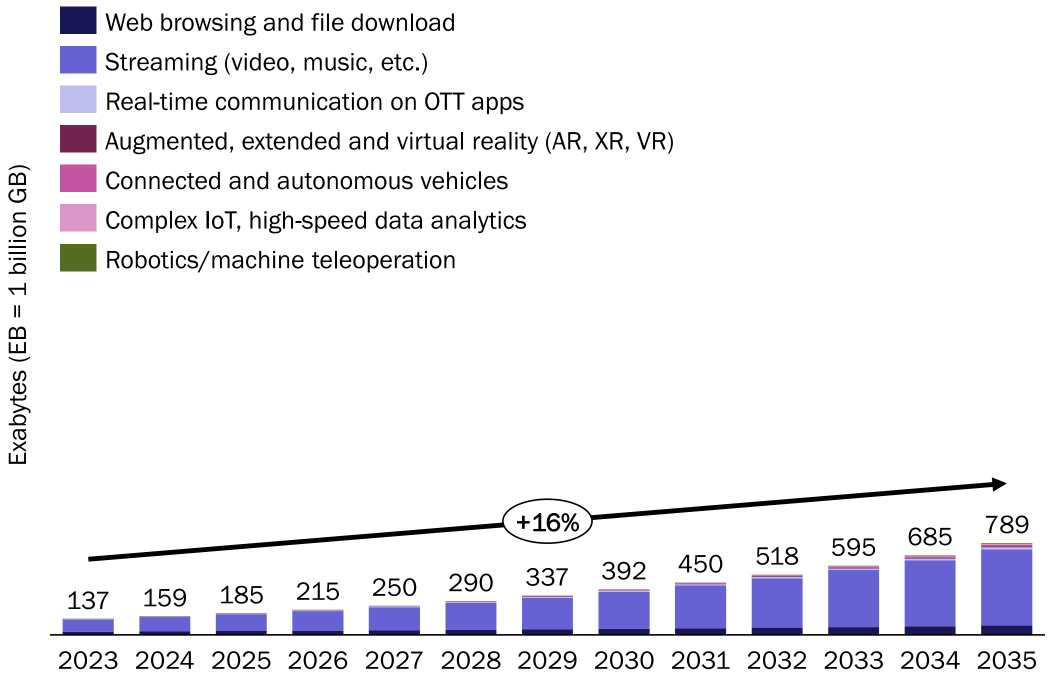

Figure 2 – Traffic by use cases under the "Median" scenario [Source: Analysys Mason, 2025]

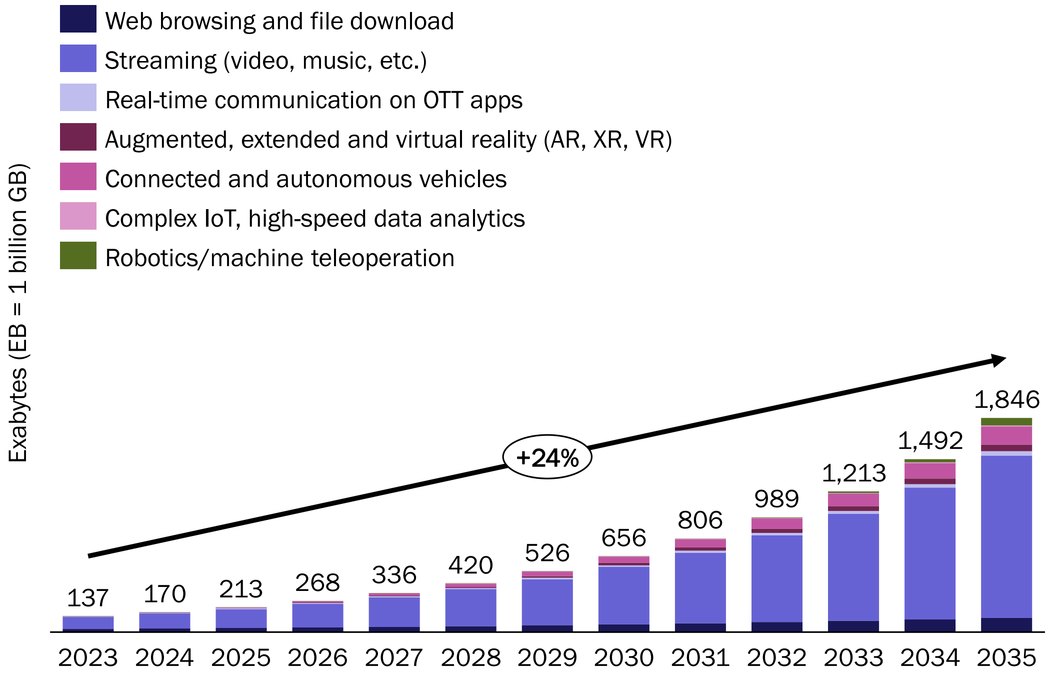

Figure 3 – Traffic by use cases under the "Increased digitalisation" scenario [Source: Analysys Mason, 2025]

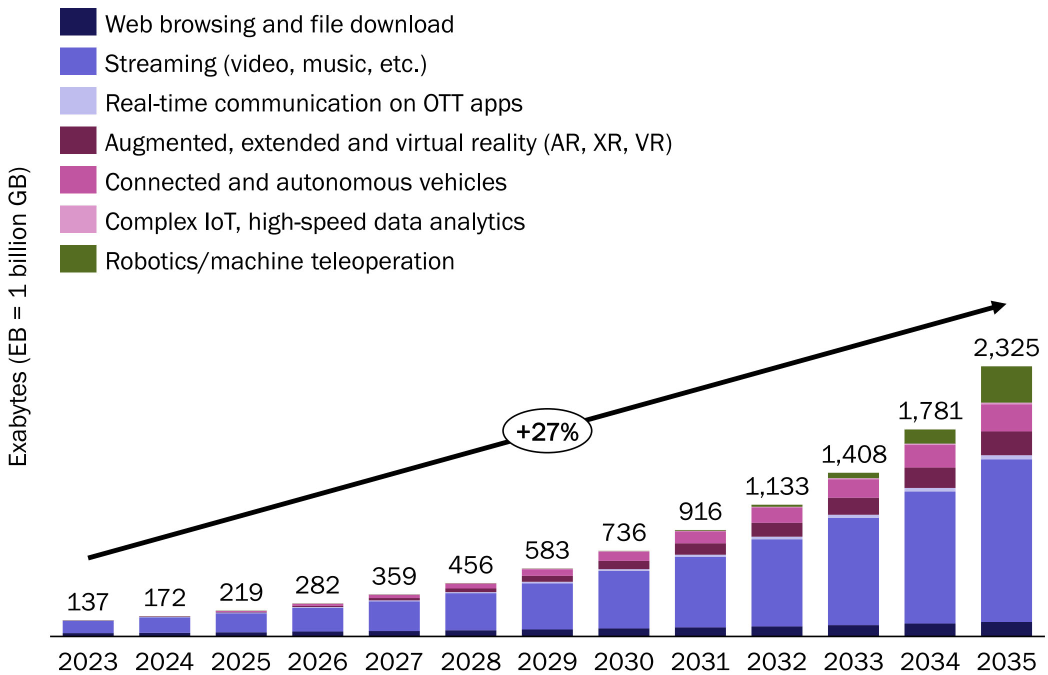

Figure 4 – Traffic by use cases under the "Disruptive uses" scenario [Source: Analysys Mason, 2025]

2.2 Phase 2: Wireless network dimensioning

2.2.1 Scope of wireless networks and network evolution scenarios

a) Scope of wireless networks considered in the study

Network dimensioning requirements are simulated by considering several types of wireless networks:

- Cellular networks (including fixed access over cellular networks): 4G, 5G (mid-range band), 5G (mid-range band – 3.5 GHz), 5G mmWave band)[10],
- Wi-Fi networks: Wi-Fi 4 (802.11n), Wi-Fi 5 (802.11ac), Wi-Fi 6 (802.11ax), Wi-Fi 7 (802.11be) and Wi-Fi 8 (802.11bn),
- Satellite networks[11]: LEO (low earth orbit), GEO (geostationary orbit)[12].

b) Wireless network evolution scenarios:

Wireless network evolution scenarios:

The scenarios represent a progressive increase in network capacity through additional spectrum allocations and/or technological developments. The scenarios described below are cumulative (e.g. scenario D includes the evolutions of scenarios A, B, C and D).

- **Scenario A "Operators maintain their current spectrum holdings":** Under this scenario, operators keep their current spectrum holdings and corresponding capacity.

- **Scenario B "Optimisation of operators' current spectrum holdings":** Under this scenario, operators optimise their current spectrum holdings, by *refarming* and *reshuffling* existing bands.

- **Scenario C "Increased network sharing, plus the deployment of existing bands where they are not yet deployed":** Under this scenario, operators increase their capacity through: (i) increased network sharing, with greater sharing of existing mobile infrastructure and (ii) the deployment of existing spectrum bands on mobile infrastructure in locations where they have not yet been deployed by any operator

- **Scenario D "Addition of new spectrum bands except the upper 6 GHz band":** Under this scenario, operators have access to and deploy new spectrum bands, except the upper 6 GHz band

- **Scenario E "Addition of new spectrum bands including the upper 6 GHz band":** Under this scenario, operators also have access to and deploy the upper 6 GHz band. Under this scenario, it is assumed that operators have access to the entire upper 6 GHz band (i.e. 700 MHz of spectrum).

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[10] 6G technology and its performances are currently being specified by 3GPP standards. Because of this degree of uncertainty, it is not taken into account in the findings presented in this document. Given the improved spectrum efficiency goals set for 6G compared to 4G and 5G, the fact of not taking 6G into account in the simulations could create the risk of underestimating the modelled cellular networks' capacity by the time this technology is deployed (between 2030 and 2035 according to ecosystem predictions)

[11] To scale the capacity requirements of satellite networks, the study adopts an approach based on aggregate capacity of GEO/non GEO satellites and a projection of this capacity during the study's timeline, based on Analysys Mason expertise (e.g.: https://www.analysysmason.com/research/content/regional-forecasts-/capacity-supply-demand-nsi040-nsi006/)

[12] As with 6G, because of uncertainties surrounding it, D2D is not taken into account in the findings presented in this document.

Main scenarios examined and their variants:

The main scenarios and their variants for testing the impact of allocating the upper 6 GHz band to mobile networks band are presented in Table 4.

Table 4 – Main scenarios and their variants for testing the impact of allocating the upper 6 GHz band to mobile networks [Source: Analysys Mason, 2025]

Baseline case	Case with the addition of the upper 6 GHz band	Findings
Scenario A	Scenario "A+6 GHz" including the upper 6 GHz band	Impact of the 6 GHz band without any other evolution of mobile networks
Scenario B	Scenario "B+6 GHz" including the upper 6 GHz band	Impact of the 6 GHz band after *refarming* and *reshuffling* existing bands
Scenario C	Scenario "C+6 GHz" including the upper 6 GHz band	Impact of the 6 GHz band after refarming and reshuffling existing bands, increased network sharing, plus the deployment of existing bands where they have not yet been deployed
Scenario D	Scenario E equivalent to "D+6 GHz"	Impact of the 6 GHz band when all other network evolutions are also implemented

Assumptions on the availability and use of spectrum *bands for cellular networks:*

Table 5 sets out the assumed timelines for network evolutions, which are activated or not depending on the chosen network scenario. The years listed here, notably the use of a spectrum band by 4G or 5G, are those included in the baseline case and can be adjusted in the study.

Table 5- Availability and use of spectrum bands [Source: Analysys Mason, 2025]

Refarming or new band	Band	Beginning of use by 4G	Beginning of use by 5G	Deployment timeline (in years)
Refarming of sites still using these bands for 2G/3G	900 MHz	Not refarmed	2025	3-6[13]
	1800 MHz	2025	Not refarmed	3
	2100 MHz	Not refarmed	2025	6
Refarming of 4G sites using these bands	700 MHz	Not applicable	2030	3
	2100 MHz	Not applicable	2030	3
	2600 MHz	Not applicable	2030	3
Increased network sharing	700 MHz	2025	2025	3
	800 MHz	2025	n/a	3
	1800 MHz	2025	n/a	3
	2100 MHz	2025	2025	3
	2600 MHz	2025	n/a	3
Deployment of existing bands where they have	700 MHz	Not applicable	2025	3
	800 MHz	2025	Not applicable	3
	1800 MHz	2025	Not applicable	3

[13] Three years for 2G sites and six years for 3G radio sites.

Refarming or new band	Band	Beginning of use by 4G	Beginning of use by 5G	Deployment timeline (in years)
not yet been deployed	2100 MHz	2025	Not applicable	3
	2600 MHz	2025	Not applicable	3
	3.5 GHz	Not applicable	2025	3
New band	1.4 GHz in SDL	Not used	2028	3
	2.6 GHz in TDD	Not used[14]	Not used	Not used
	Lower 3.5 GHz band	Not used	2028	3
	Upper 3.5 GHz band	Not used[15]	Not used	Not used
	Upper 6 GHz band	Not used	2030	3
	26 GHz	Not used	2030	3

The study also considers assumptions on existing wireless networks' engineering rules, notably the timeline for MIMO evolutions for each cellular technology and each type of spectrum (lower band, mid-band and mmWave band).

In addition to the main scenarios and their variants (see above), sensitivity analyses were performed to assess the impact of a given spectrum band (e.g. the impact of using/not using the mmWave band), the impact of the feedback loop (e.g. activating operator and/or user feedback), the carbon footprint of phase 3 of the study (e.g. improvement of the embodied carbon footprint or improvement of the energy efficiency of the devices used).

2.2.2 Methodological principles of the "transition matrix"

The model establishes assumptions for the distribution of the estimated volume of traffic generated by each of the use cases to each of the networks by using a transition matrix.

The aim of this transition matrix is to model the interactions between different technologies, use cases, and geotypes, while incorporating the evolution of user behaviour and network performance over time, as illustrated in Figure 5.

[14] Arcep plans on allocating the 2.6 GHz band in TDD to professional mobile networks (PMR) which are local networks designed to satisfy the specific needs of certain businesses and organisations, also known as verticals, typically operating in infrastructure-related sectors.

[15] Arcep recently stated that the "3.8 – 4.2 GHz band is currently – and due to continue to be – used by fixed satellite service (FSS) earth stations, which are nevertheless deployed in a limited number of locations across the country," and that "harmonisation work being done by CEPT at the European level is targeting use in "TDD" and local mode". Spectrum blocks between 3.8 GHz and 4 GHz area already available for use in trials.

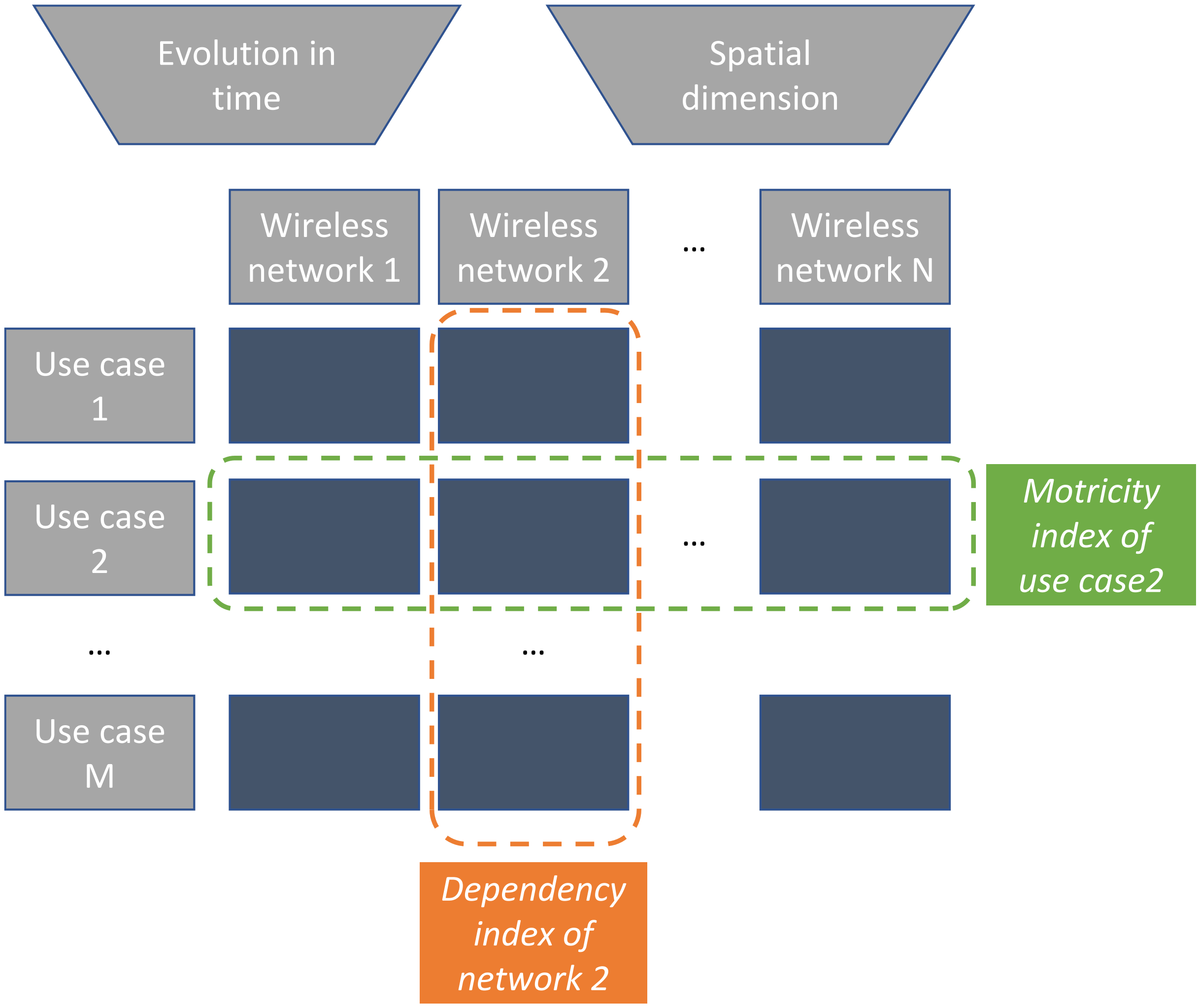

Figure 5 – Illustration of the concept of “transition matrix” [Source: Arcep, 2024]

This transition matrix is established using the methodology described below, and illustrated in Figure 6.

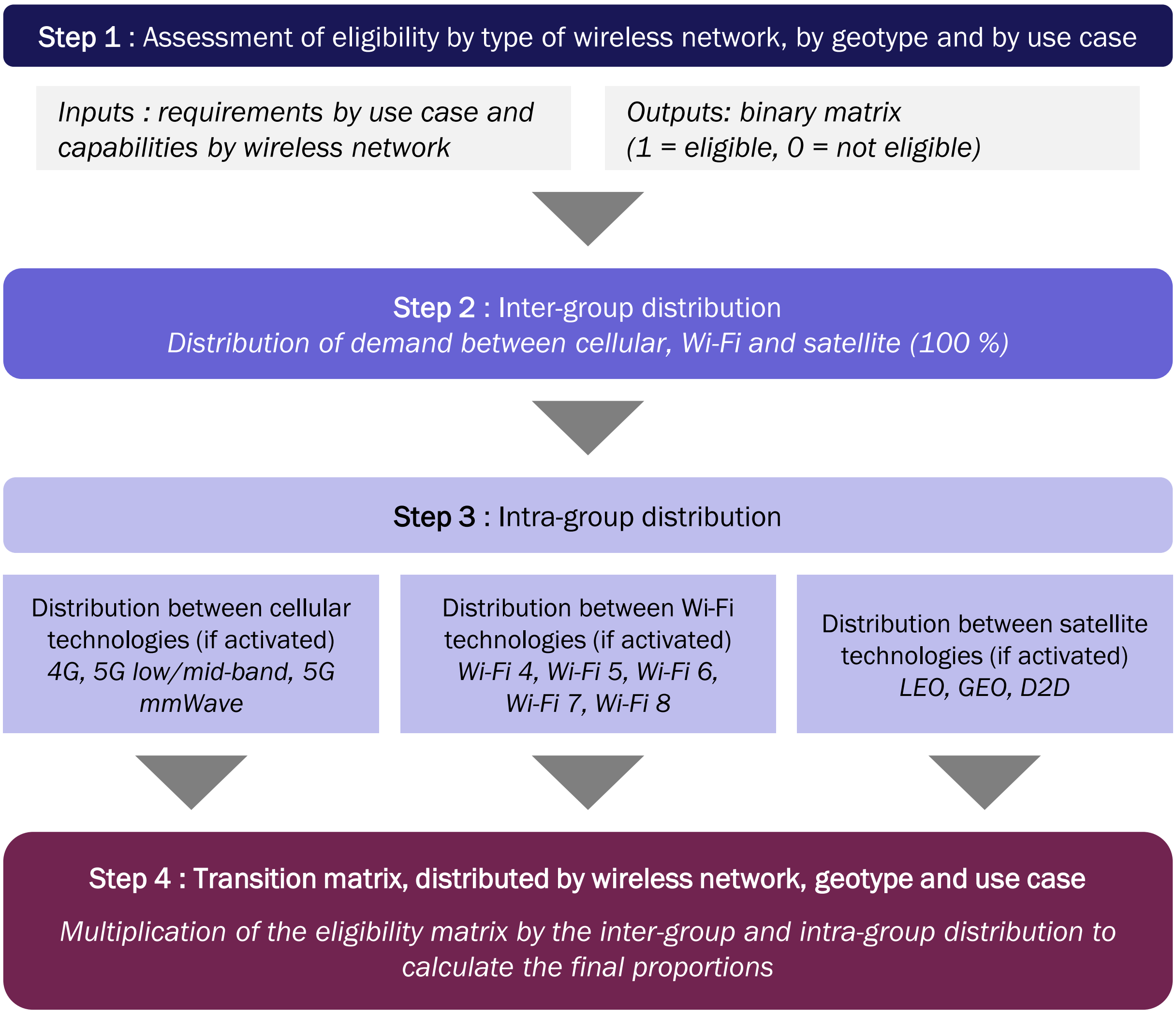

Figure 6 –Calculation methodology for the transition matrix [Source: Analysys Mason, 2024]

- *Step 1: Assessment of technology eligibility:*

  First, a comparison is made between use cases' requirements and the properties of the different wireless technologies, to determine which wireless technologies are capable of satisfying each use case based on upstream speeds (downstream speeds, latency and jitter respectively).
- *Step 2: Inter-group distribution:*

  Second, for each use case, a distribution key for the share of traffic between each group of wireless technologies (i.e. cellular, Wi-Fi and satellite) is estimated for each geotype. This estimate changes over time and factors in:
  - differences in coverage levels between wireless technology groups to identify satellite networks' percentage (notably in the most rural areas);
  - an offloading factor[16] is an assumption associated with each use case and included in the calculation of demand associated with each network before the application of the feedback loop (e.g. switching to Wi-Fi from the cellular network when both networks are available) to identify Wi-Fi networks' share. This factor can vary by

[16] Based on past experience, Analysys Mason consider an offloading factor of 80–85% to be a reasonable estimate. This assumption is consistent with the comparisons made based on global data on total traffic, which indicate that the percentage of data traffic relayed over Wi-Fi stands at between 70% and 90%.

use case location ("Mainly indoor", "Indoor and outdoor" or "Outdoor"), by geotype and by year. The results presented in Phase 3 of this document were established based on the assumption that the offloading factor is fixed over time.

- *Step 3: Intra-group distribution:*

  An additional analysis is then performed to determine the percentage of traffic within each group attributed to each specific technology.
- *Step 4: Combination of previous steps:*

  Last, the results obtained during the previous steps are combined to generate a transition matrix that estimates the traffic distribution for each use case, according to geotypes and available technologies, for each year.

2.2.3 Methodological principles of the "Feedback loop"

The study considers two feedback mechanisms between the dimensioning of wireless network infrastructures on the one hand, and the evolution of wireless uses on the other:

- **Feedback between the capacity available on the networks and the incentive for users to increase their usage, reflecting an operator's choice** to offer its mobile subscribers a greater data allowance if capacity is available on its networks (e.g. to increase its market share or not lose some);
- **Feedback between the level of saturation on each of the networks and the distribution of demand between networks, reflecting the behaviour of end users**, for instance forcing their device to connect to Wi-Fi rather than a mobile network (or vice-versa) if the quality of one of those networks is unsatisfactory (e.g. due to network saturation).

These two feedback mechanisms are modelled respectively using the following approach:

- Traffic forecasts in year N+1 are increased based on the level of network utilisation in year N. For instance, if the network is used at 60% and maximum utilisation is 80%, at the national level, traffic in year N+1 is increased by a maximum 33.3% (= (80%–60%)/60%). This increase occurs after application of the transition matrix.
- The volume of traffic on the network in year N+1 is adjusted based on the level of network utilisation in year N, in a given geotype. As a result, if the network is saturated, more traffic is offloaded to another underused network, but without the utilisation of that network exceeding its maximum level.

The specific contribution of each of these feedback loop mechanisms in estimating traffic is taken into consideration without distinction in the results presented in Section 3.

2.3 Approaches to estimating radio site requirements

In the rest of this document, the study uses the terms "radio site" and "physical site" as follows:

- **"Radio site" or "mobile site":** this refers to a point of presence for an operator, regardless of the technology/technologies or spectrum bands deployed by this operator at this location. If, for instance, operator "A" has deployed equipment using 2G 900 MHz, 4G 800 MHz and 4G 2600 MHz technologies and spectrum at a given location, this corresponds to one radio site. If operator "B" has deployed 3G 900 MHz and 4G 2600 MHz technologies and spectrum at the same location, this corresponds to a second radio site.

- **"Physical site" or "tower":** this refers to a given location that hosts equipment for one or several radio sites. The two radio sites belonging to operator "A" and operator "B" in the previous example correspond to a single physical site or tower. By definition, there can be up to four radio sites per physical site, if all four of the mobile operators are present at the same location.

In what follows, the results presented are expressed in radio sites per operator and per year.

To calculate the number of new radio sites required to satisfy unmet capacity needs, their unit capacity must be determined, according to the spectrum bands deployed on them. Two approaches were adopted for spectrum bands already deployed by operators, as presented in Table 6:

- The first approach – more optimistic – refers to a situation where an operator deploys new sites with the largest possible capacity in order to minimise the number of sites.
- The second approach – more conservative –refers to a situation where an operator deploys new sites with the average capacity of existing sites. This is a less efficient but potentially more realistic approach in the short term as it reflects the constraints faced by operators.

Table 6 – Example of a capacity calculation illustrating the two approaches to dimensioning new radio sites [Source: Analysys Mason, 2025]

	Number of existing radio sites (#)	**Capacity per radio site for each technology (Mbit/s)**	**Capacity per new radio site**	
			whose capacity is greater than an existing site (Mbit/s) for existing bands (1st approach)	**whose capacity is equal to that of an existing site (Mbit/s) for existing bands (2nd approach)**
Radio sites with 4G	1000	40		
Radio sites with 5G	500	100		
New radio sites			140 = 40 + 100	90 $= \frac{1000 \times 40 + 500 \times 100}{1000}$

2.4 Phase 3: Assessing wireless networks' carbon footprint

The carbon footprint of a human activity can be classified into three categories or "Scopes", according to the "GHG Protocol"[17], a global frame of reference for measuring and managing greenhouse gases (GHG) within an organisation.

Table 7 – GHG accounting scopes [Source: Bpifrance[18], 2024]

Category	**Definition**
Scope 1	Corresponds to direct GHG emissions from sources that are owned or controlled by the company (notably fuel emissions on site).
Scope 2	Covers indirect GHG emissions associated with energy consumption (notably electricity and heating).
Scope 3	Includes indirect GHG emissions beyond the company's control, including activities upstream and downstream of the company's value chain.

[17] https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

[18] https://bigmedia.bpifrance.fr/nos-dossiers/scope-1-2-et-3-du-bilan-carbone-definition-perimetres-exemples

In this study, we implemented an approach to carbon accounting based on a life cycle analysis, and considered:

- wireless networks (cellular[19], Wi-Fi[20] and satellites) and the devices which use them[21], but not data centres;
- embodied GHG (extraction and equipment production, end of life, i.e. Scope 3), approximated by calculating the impact of producing the equipment (negligible end of life);
- operational GHG (usage, maintenance and installation of assets, i.e. Scope 1 and Scope 2 and potentially elements from Scope 3 if some of these activities are outsourced/offshored) approximated by calculating the impact of actual usage (energy consumption).

The energy mix was calculated based on French government[22] and RTE[23] data.

Table 8 below presents an estimate of the energy mix and associated carbon intensity.

Table 8 – Energy production in France [Source: GIEC/IPCC, 2018, Ministry of Ecology, 2024, and RTE, 2022]

Energy source	$kgCO_2e/kWh$[24]	Share in 2023 (%)[25]	Share in 2030 (%)[26]	Share in 2040 (%)[26]
Nuclear	0.0120	63.4	60.1	45.0
Renewable	0.0195	26.8	34.8	53.8
Fossil fuel-based thermal	~0.6500	9.7	5.1	1.0
Other	*Unavailable*	0.1	0.1	0.1
Weighted average	***N/A***	**0.076**	**0.047**	**0.022**

3 Results and key findings

The results of the study's main scenarios summarised below refer to the first approach to dimensioning radio sites (i.e. to the situation in which an operator deploys new sites with the largest possible capacity to minimise the number of sites). The starting point corresponds to the radio sites deployed by operators in 2024.

[19] Modelling the carbon footprint of cellular networks gives separate consideration to the impact of a new physical site (i.e. a new tower), or a new radio site (i.e. new radio equipment).

[20] This includes Wi-Fi routers but not wireline backhaul (e.g.: FTTx PON).

[21] Mobile phones (smartphones), laptop computers (personal and work), computer screens, televisions, tablets, AR/VR (LCD and OLED) headsets and IoT modules.

[22] Energy mix in 2023: https://www.statistiques.developpement-durable.gouv.fr/chiffres-cles-de-lenergie-edition-2024

[23] Energy mix in 2030 and 2040, "Scenario N1 – reference": https://assets.rte-france.com/prod/public/2022-06/FE2050%20_Rapport%20complet_ANNEXES.pdf

[24] Table A.III.2 in Annex III à https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[25] https://www.statistiques.developpement-durable.gouv.fr/chiffres-cles-de-lenergie-edition-2024

[26] Scenario N1 – referencing: https://assets.rte-france.com/prod/public/2022-06/FE2050%20_Rapport%20complet_ANNEXES.pdf

3.1 Results of the main scenarios

3.1.1 Scenario A “Mobile operators maintain their current spectrum holdings”

Table 9 presents the impact of allocating the upper 6 GHz band to mobile networks for network scenario A and for each of the demand evolution scenarios.

Table 9 – Impact of allocating the upper 6 GHz band to mobile networks for scenario A [Source: Analysys Mason, 2025]

Demand scenario	Network scenario A		Network scenario A+6 GHz including the upper 6 GHz band	
	New sites required per operator and per year[27]	Cumulative carbon footprint[28] (in $MtCO_2e$)	New sites required per operator and per year	Cumulative carbon footprint
Restrained consumption	3	140.53	-	140.49
Median	1417	152.78	190	146.71
Increased digitalisation	4987	174.19	1444	156.18
Disruptive uses	6278	181.50	2284	161.36

Under network scenario A “Operators maintain their current spectrum holdings”:

- The number of additional radio sites required between now and 2035 becomes very high starting with the “Increased digitalisation” demand scenario with or without the upper 6 GHz band.
- The other network evolution scenarios (refarming, sharing, etc.) that can help absorb traffic growth, and thereby reduce the number of radio sites required, would thus become necessary.
- The upper 6 GHz band offers a very significant reduction in the number of additional radio sites required, from –51% to –100% depending on the demand scenario.

3.1.2 Scenario B “Optimisation of operators’ current spectrum holdings”

Table 10 presents the impact of allocating the upper 6 GHz band to mobile networks for network scenario B and for each of the four evolution of demand scenarios.

[27] As in the other results tables in this document, “sites” refers to “radio sites”, and the values correspond to the average number of sites per operator and per year over the period 2025-2035.

Each of France’s four mobile operators deploys an average of around 1,000 new radio sites per year (between 800 and 1200). These new radio sites can be deployed on a “physical site” or “tower” on which another operator is already present.

[28] Cumulative carbon emissions between 2023 and 2035 including both network assets and devices. It should be noted that devices account for the majority of carbon emissions (over 85% in all of the modelled scenarios).

Table 10 – Impact of allocating the upper 6 GHz band to mobile networks for scenario B [Source: Analysys Mason, 2025]

Demand scenario	Network scenario B		Network scenario B+6 GHz including the upper 6 GHz band	
	New sites required per operator and per year	Cumulative carbon footprint (in $MtCO_2e$)	New sites required per operator and per year	Cumulative carbon footprint
Restrained consumption	1	140.75	-	140.72
Median	1308	152.26	181	146.82
Increased digitalisation	4724	172.63	1 325	155.50
Disruptive uses	5960	179.55	2 000	159.51

Under network scenario B "Optimisation of operators' current spectrum holdings", the results are close to those of network scenario A, as *refarming* the 900 MHz, 1800 MHz and 2100 MHz band spectrum being used for 2G/3G to 4G/5G technologies, coupled with *refarming* the 700 MHz, 2100 MHz and 2600 MHz band spectrum used for 4G to 5G technology, provides only a limited amount of additional capacity.

3.1.3 Scenario C "Increased network sharing plus deployment of existing bands where they have not yet been deployed"

Table 11 presents the impact of allocating the upper 6 GHz band to mobile networks for network scenario C and for each of the four evolution of demand scenarios.

Table 11 – Impact of allocating the upper 6 GHz band to mobile networks for scenario C [Source: Analysys Mason, 2025]

Demand scenario	Network scenario C		Network scenario C+6 GHz including the upper 6 GHz band	
	New sites required per operator and per year	Cumulative carbon footprint (in $MtCO_2e$)	New sites required per operator and per year	Cumulative carbon footprint
Restrained consumption	-	142.49	-	142.49
Median	129	147.53	35	147.27
Increased digitalisation	2314	156.47	1054	152.09
Disruptive uses	3364	160.93	1800	155.00

The results of Network scenario C "Increased network sharing plus the deployment of existing bands where they have not yet been deployed" reveal that this scenario enables a very significant reduction in the number of new sites required to satisfy demand, compared to network scenario B.

The results of scenario C make it possible to assess the share of new sites tied to demand, which are not an installation on existing towers tied to network sharing, or the addition of the deployment of existing bands where they have not yet been deployed. This number of sites tied to network sharing and/or the added deployment of existing bands where they have not yet been deployed is not reflected in the following table, nor in the other tables of results based on scenarios C, D or E[29].

3.1.4 Scenario D "Addition of new spectrum bands except the upper 6 GHz band"

Table 12 presents the impact of allocating the upper 6 GHz band to mobile networks for network scenario D and for each of the four evolution of demand scenarios.

Table 12 – Impact of allocating the upper 6 GHz band to mobile networks for scenario D [Source: Analysys Mason, 2025]

Demand scenario	Network scenario D		Network scenario E	
	New sites required per operator and per year	Cumulative carbon footprint (in $MtCO_2e$)	New sites required per operator and per year	Cumulative carbon footprint
Restrained consumption	-	142.60	-	142.60
Median	64	147.45	11	147.33
Increased digitalisation	1297	153.27	733	151.11
Disruptive uses	1927	156.00	1188	153.06

The comparison between scenarios D and E represents the most conservative estimate of the impact of the upper 6 GHz band deployment of all the scenarios. The number of additional sites remains high under the "Disruptive uses" demand scenario, but the cumulative impact of refarming, increased sharing, plus the deployment of existing bands where they have not yet been deployed, the addition of new bands, and the addition of the upper 6 GHz band reduced the number of sites required, per operator and per year between now and 2035 by around 40% for the "increased digitalisation" and "disruptive uses" scenarios, which translates into a required network densification effort of between 733 and 1,188 sites per operator and per year, between now and 2035 for these two evolution of demand scenarios.

3.2 Study findings and limitations

Based on the results of the model, several findings can be deduced to assess and qualify the magnitude of wireless networks' (and especially cellular networks') need for additional network capacity, according to the different evolution of demand scenarios:

Under the "Restrained consumption" demand scenario:

- The upper 6 GHz band has very little, if not zero, impact on mobile networks since the number of additional sites required is very small (a maximum of three sites per operator and per year), if not zero, regardless of the network scenario;
- Wi-Fi networks do not require additional access points in the absence of the upper 6 GHz band.

For the three other evolution of demand scenarios, the impact of the upper 6 GHz band on mobile networks varies from mild to very significant, offering the ability to save between 53 (for the "median" evolution of demand scenario and for scenario D) and close to 4,000 (for the "disruptive uses" evolution

[29] This addition of sites corresponds to a scheduled evolution under scenario C. The results of scenario C thus refer to a number of additional (not scheduled) sites required to satisfy demand on top of scheduled evolutions under this scenario. These scheduled evolutions correspond to the addition of 2,133 sites per operator and per year between now and 2035.

of demand scenario and for scenario A) additional sites per operator and per year between now and 2035.

Regarding the carbon impact of allocating the upper 6 GHz band to mobile operators, the results generally indicate a reduction in each network evolution scenario's carbon footprint, particularly for the most demand-intensive evolution scenarios (i.e. "increased digitalisation", "disruptive uses"). These results also show that devices represent the majority of carbon emissions (more than 85% in every modelled scenario).

Moreover, although the findings detailed above make it possible to pinpoint trends on additional capacity requirements and to assess the risk of network congestion according to the different evolution of demand scenarios, the study includes a certain number of limitations and uncertainties. Insofar as possible, some of these limitations/uncertainties were evaluated through sensitivity analyses, factoring in the study's original aspects. The main limitations are tied in particular to the following:

- Wi-Fi modelling is performed in a simplified manner: the risks of interference with other nearby access points (such as those belonging to neighbours in an apartment building) are not taken into account, and each access point is assigned the maximum unit capacity based on its generation (Wi-Fi 4 to Wi-Fi 8).
- The number of additional new sites required is tied solely to the additional capacity required and to the unit capacity provided by each new site, and does not take into account the limitations of cellular densification (intercell interference, operational limitations, etc.).
- The various sources used to establish demand forecasts do not distinguish between demand associated with public cellular networks (those modelled) and demand associated with private cellular networks, so it is possible that private demand is included in the model although it should not be. The impact of this is minor, as demand associated with private cellular networks is much lower than demand associated with public cellular networks. Moreover, the disparities between the different demand scenarios are far greater than the potential disparities due to the inclusion or not of demand associated with private cellular networks.
- As with all demand forecasts, there are uncertainties inherent in the data for projecting demand for each use case. The evolutions tied to artificial intelligence (AI) and its adoption by users – notably its impact on the proportion of upstream versus downstream traffic – could also affect demand forecasts.
- The transition matrix is based on the use of a single value for each of the different requirements (downstream speed, upstream speed, latency) of each use case, and for the performance features of each wireless technology for these same indicator, which is a simplification of the possibility for each wireless technology to enable a use case. However, the sensitivity on these parameters of the transition matrix leads to only minimal changes in the model's results.
- Regarding the carbon footprint, there are uncertainties tied to unit data (embodied carbon emissions data, energy consumption). Additionally, data centres were not factored into the carbon footprint, and the approach used to assess the carbon footprint of each scenario did not consider environmental impacts based on a consequential life cycle analysis (LCA).