European Commission

Spectrum policy

Analysis of technology trends, future needs and demand for spectrum in line with Art.9 of the RSPP

FINAL REPORT

A study prepared for the European Commission DG Communications Networks, Content & Technology

This study was carried out for the European Commission by

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Contents

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1 Executive summary (short version)

This section is the short executive summary that summarises the work carried out by Analysys Mason Limited on behalf of the European Commission, DG Communications Networks, Content and Technology ('the Commission') in relation to the implementation of Article 9 of the first Radio Spectrum Policy Programme (RSPP), by analysing technology, consumer and community trends, and assessing future needs and demand for spectrum usage.

1.1 Objectives of the study

The primary objective of this study is to assess incremental demand for spectrum usage for particular categories of use (e.g. mobile, terrestrial broadcasting, defence, aeronautical, etc.) over the next ten years in the EU-27, within the frequency range from 400 MHz to 6 GHz. It does not aim to forecast any changes that may be made to the spectrum *designations* to those categories of use, although such designations could be informed by future spectrum usage needs.

Our analysis assesses levels of spectrum usage demand broken down into the various types of applications that use the spectrum. In order to be consistent with the Commission Implementing Decision (2013/195/EU), we have used the same 14 application categories included in the Decision:

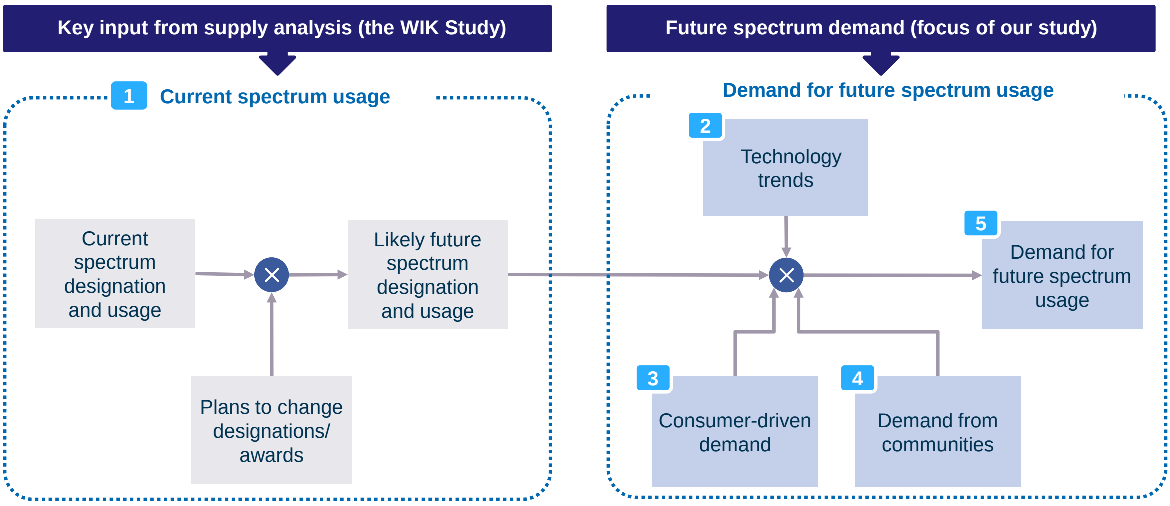
1. Aeronautical, maritime and civil radiolocation and navigation systems (AMCRN)
2. Terrestrial broadcasting (Broadcasting)
3. Cellular/BWA (Mobile)
4. Defence systems (Defence)
5. Fixed links (Fixed)
6. Intelligent transport systems (ITS)
7. Meteorology (MET)
8. Private mobile radio/public access mobile radio (PMR/PAMR)
9. Programme making and special events (PMSE)
10. Public protection, disaster relief (PPDR)
11. Radio astronomy (Science)
12. Satellite systems (Satellite)
13. Short-range devices (SRDs)
14. WLAN/RLAN (WLAN).[1]

1.2 Overview of the methodology used

The main objective of this project is to estimate the demand for spectrum usage in the next ten years. We began by developing an understanding of current spectrum usage, broken down by category and frequency band. We then applied different growth factors based on an analysis of technology trends, and consumer and community demand. As a result, we arrived at a picture of demand for future spectrum usage, broken down by spectrum band, application and country. The following figure shows the overall methodology of our study.

1 Formerly called wideband data transmission systems.

Figure 1.1: Overall methodology of the study [Source: Analysys Mason, 2013]



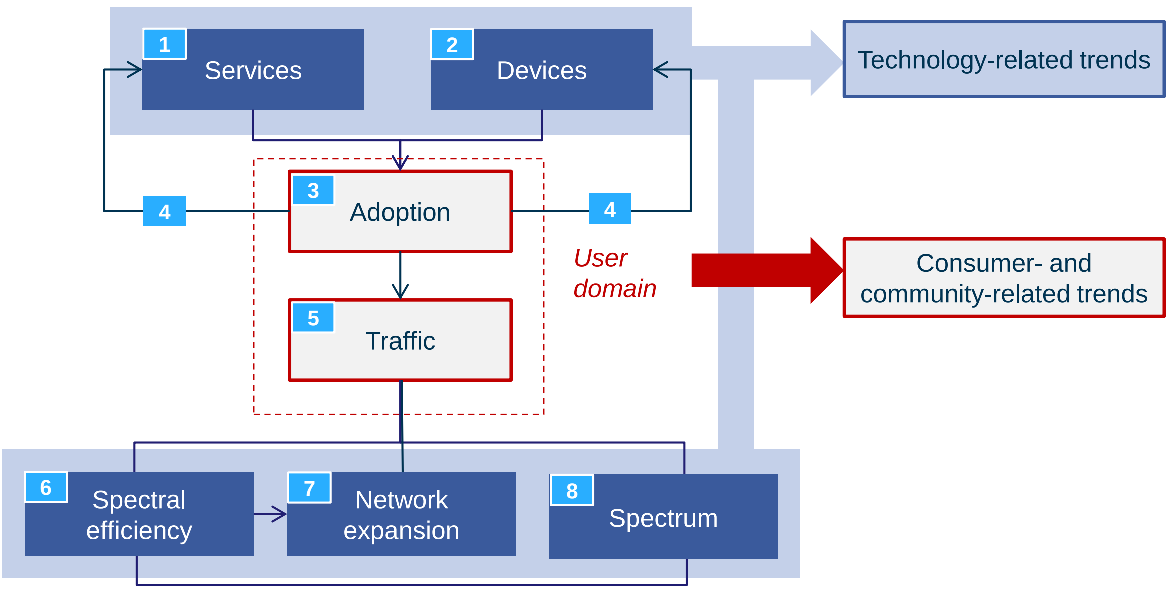
1.2.1 Step 1: Current spectrum usage

Due to some lack of quantitative data regarding current demand for spectrum usage across the EU-27, we decided (in agreement with the EC) to take a *qualitative* approach, taking as a starting point the qualitative estimates provided in the WIK Study and allocate a range of quantitative usage values for each step on this scale. We present the results of our analysis of current spectrum usage in a series of 'heatmaps'.

1.2.2 Steps 2, 3 and 4: Identification and assessment of trends

In the next three steps, we identified and assessed on an individual basis (a) technology-related trends, and (b) consumer- and community-related trends that affect spectrum usage, for each of the categories of usage over the next ten years. Our methodology for this is shown in Figure 1.2 below.

Figure 1.2: Methodology for identifying and assessing technology, consumer and community trends [Source: Analysys Mason, 2013]



We identified the main technology, consumer and community trends for each category of spectrum use that we and stakeholders believe are relevant in terms of future demand. We then assessed the impact that each trend will have on spectrum usage demand, taking into consideration the information gathered from our desk research, our interviews with stakeholders, and inputs from the workshops. The impact assessment was made for three periods: short term (2012–2014); medium term (2012–2017); and long term (2012–2022).

1.2.3 Step 5: Demand for future spectrum usage

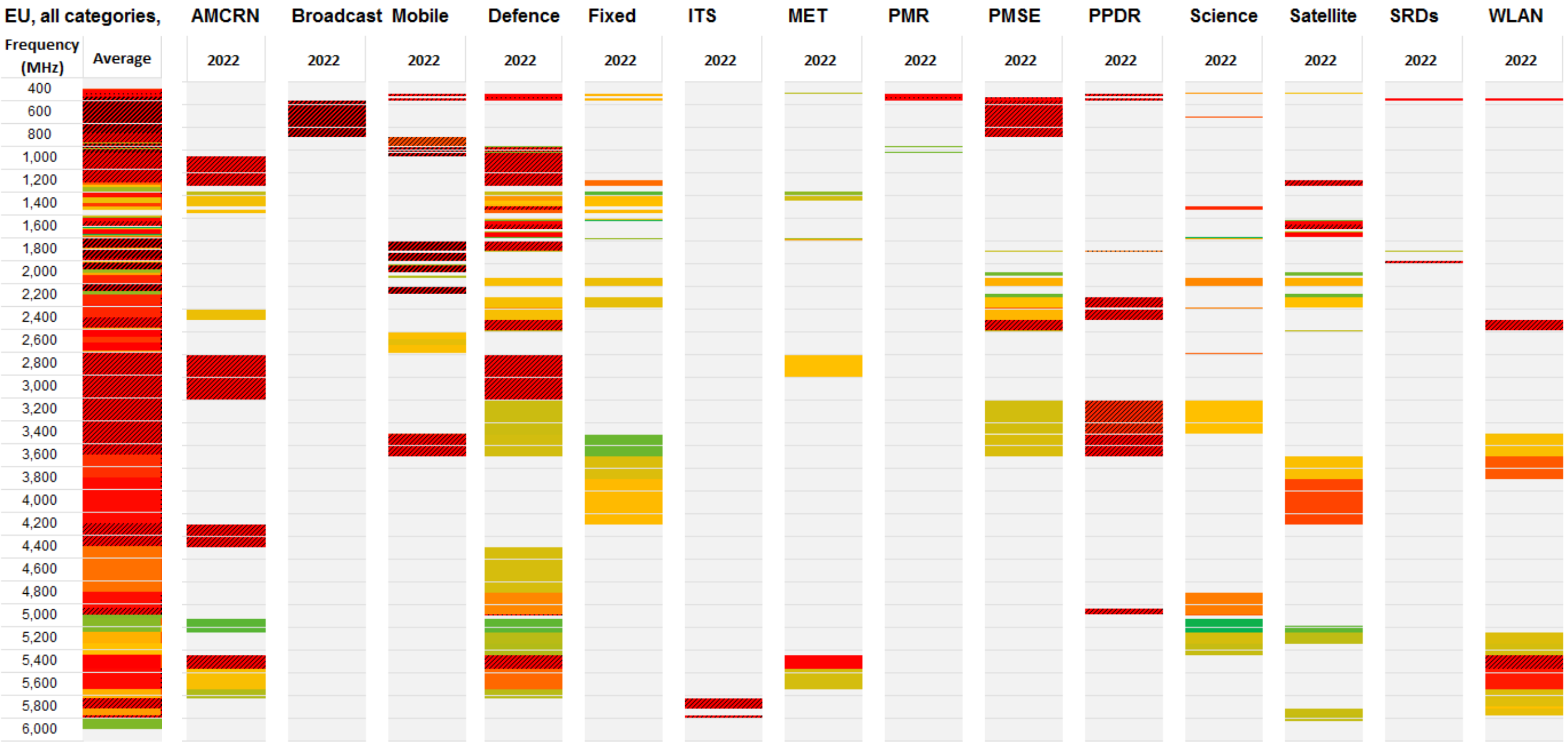
In this final step we combined all the trends to ascertain their collective effect (in qualitative terms) on spectrum demand in the short, medium and long term. We then applied these trends to the current usage levels and calculated, again on a qualitative basis, the expected future spectrum usage. We also developed minimum, average and maximum growth scenarios to cope with uncertainty in the data and different views on future growths. The results are presented as heatmaps: for each application category, we present heatmaps of spectrum usage across the whole EU-27 in 2014, 2017 and 2022, assuming (a) a minimum growth scenario, or (b) a maximum growth scenario. In addition, we give heatmaps for usage in the focus countries in 2022, based on an average growth scenario.

On the basis of this analysis, we identified areas in which future usage may exceed current designation, and over which period of time this may occur. Finally, we drew conclusions and developed recommendations for each category.

1.3 Future spectrum usage

Figure 1.3 overleaf shows a heatmap of spectrum usage in 2022 across the whole EU-27, broken down by application category. This is based on average current spectrum usage and the average growth scenario. As can be seen, there are key regions of spectrum that are likely to experience demand in excess of 100% of the designated band by 2022 (shown in the figure as red with diagonal shading). Some application categories, such as AMCRN, exhibit high usage across a larger number of bands than others.

Figure 1.3: Heatmap showing spectrum usage in 2022, by application category and total, based on average current usage and the average growth scenario [Source: Analysys Mason, 2013]



1.4 Overall conclusions, recommendations and potential next steps

Overall, even though we have not been able to estimate quantitatively the demand for future spectrum usage, we believe that our results provide a solid base to inform future spectrum usage and needs, and to highlight areas that require further work to improve the accuracy of the results. In particular, we believe that the results of this study are very useful to inform the debate about the direction, scale and timing of future spectrum usage demand, together with the key drivers that will determine this demand. However, there are some issues that need further work, and some actions to be taken.

- There are significant differences in spectrum usage across the focus countries, both currently and in the future. This is also shown by the differences between the minimum and maximum usage in the EU-27 as a whole. The main differences are between 2 GHz and 5 GHz frequency ranges.

- For most application categories there is significant uncertainty regarding the impact on spectrum demand of the different technology, consumer and community trends, particularly in the longer term. Many research houses that provide forecasts for the different trends do not provide data for the long term. Moreover, estimates vary widely between the various research houses, and their forecasts are adjusted annually.

- There are also some uncertainties regarding the designation of some spectrum bands in some countries, which make it difficult to accurately estimate the demand for future spectrum usage. One example is the possible designation of spectrum in the 700 MHz band (in the 694–790 MHz range) to mobile services.

- Future spectrum usage – across most frequencies – will increase significantly over the next 10 years. However specific nature of the congestion problem is completely different in the short term, medium term and long term. Generally, congestion problems begin to appear mainly in the medium term.

- Since for most categories demand for spectrum is increasing, more sophisticated sharing of spectrum is increasingly important – for example based on white spaces. It is therefore important to invest more time and resources in identifying and developing possibilities for spectrum-sharing.

- It is important to note that many bands are not exclusively used by one type of application, but are often shared with other categories. In theory, therefore, clearing this spectrum for other users would require the sharing services to vacate the spectrum as well. For this reason, many of the results of any calculations will tend to be lower than may be necessary in reality.

- For some categories, spectrum may also not be used on a regular basis, or only in limited geographical areas – for example, some of the spectrum allocated for defence use. This may raise the possibility for some of this spectrum to be made available for use by other categories under carefully designed conditions.

- Some categories are interrelated, and therefore in some cases demand by one category will reduce demand by another. For example, the spectrum demand for both mobile and Wi-Fi is driven mainly by the growth in on-demand video and audio-visual services on tablets, smartphones and other devices. In such cases, satisfying demand from one category is likely to be at the detriment of the other category – and different stakeholders will have different perspectives on how such competing demands should be met.

- Some actions that are currently being discussed to reduce future congestion problems have not been included in our qualitative estimations – for example, there are some studies ongoing in Europe into extending SRD bands above 870 MHz.

- Existing data on current spectrum *usage* is not reliable enough to form a basis for accurate quantitative forecasts of spectrum *usage* demand. To remedy this, it is important that Member States improve their knowledge of current spectrum usage and make this data publicly available.

- There are concerns about the 14 application categories and how these should be categorised and demand estimated. It is important to be clear about which applications are included under each category, and the exact mapping onto EFIS layers, in order to minimise duplication or overlaps.

- We would like to note that the scope of this study does not include any assessment of the societal and economic benefits of spectrum and the various applications that use it. We have not taken into account any environmental issues.

2 Executive summary (extended version)

This report summarises the work carried out by Analysys Mason Limited on behalf of the European Commission, DG Communications Networks, Content and Technology ('the Commission') in relation to the implementation of Article 9 of the first Radio Spectrum Policy Programme (RSPP), by analysing technology, consumer and community trends, and assessing future needs and demand for spectrum usage.

This executive summary is structured as follows:

- a brief summary of the objectives of the study, and an overview of the methodology we have used to analyse technology, consumer and community trends, and to assess future needs and demand for spectrum in the EU
- key findings from our analysis of technology, consumer and community trends
- our conclusions regarding future demand for spectrum usage across the whole EU-27, broken down by application category
- overall conclusions, a number of recommendations and suggested next steps.

2.1 Objectives of the study and methodology used

The primary objective of this study is to assess incremental demand for spectrum usage for particular categories of use (e.g. mobile, terrestrial broadcasting, defence, aeronautical, etc.) over the next ten years in the EU-27, within the frequency range from 400 MHz to 6 GHz. It does not aim to forecast any changes that may be made to the spectrum *designations* to those categories of use, although such designations could be informed by future spectrum usage needs.

A key component of the study was input from Member States and industry stakeholders. Four workshops were held in Brussels, attended by over 100 participants, and we also held a number of interviews with key stakeholders. Analysys Mason would like to thank all those organisations and individuals who have contributed to the study by participating in these events, or by providing other inputs to the study (e.g. written submissions). This input has been very valuable to the study team and has informed our conclusions and recommendations.

2.1.1 Definitions of the categories of spectrum use

Our analysis assesses levels of spectrum usage demand broken down into the various types of applications that use the spectrum. In order to be consistent with the Commission Implementing Decision (2013/195/EU), we have used the same 14 application categories included in the Decision:

1. Aeronautical, maritime and civil radiolocation and navigation systems (AMCRN)
2. Terrestrial broadcasting (Broadcasting)
3. Cellular/BWA (Mobile)
4. Defence systems (Defence)
5. Fixed links (Fixed)
6. Intelligent transport systems (ITS)

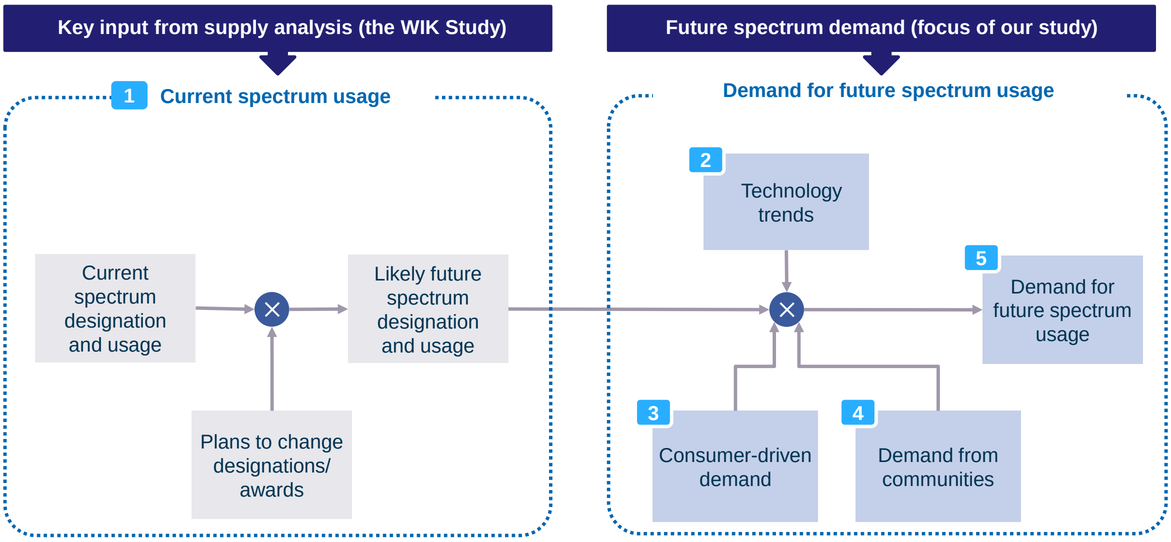
7. Meteorology (MET)
8. Private mobile radio/public access mobile radio (PMR/PAMR)
9. Programme making and special events (PMSE)
10. Public protection, disaster relief (PPDR)
11. Radio astronomy (Science)
12. Satellite systems (Satellite)
13. Short-range devices (SRDs)
14. WLAN/RLAN (WLAN).[2]

We have some concerns about these application categories, and how different applications should be categorised and demand estimated. This is based on significant criticism by stakeholders during the workshops about the main criteria behind the definitions, and the potential overlap between categories. It is important to be clear about which applications are included under each category and the exact mapping with EFIS layers, to minimise duplication or overlaps.

2.1.2 Overview of the methodology used

The main objective of this project is to estimate the demand for spectrum usage in the next ten years. We began by developing an understanding of current spectrum usage, broken down by category and frequency band. We then applied different growth factors based on an analysis of technology trends, and consumer and community demand. As a result, we arrived at a picture of demand for future spectrum usage, broken down by spectrum band, application and country. The following figure shows the overall methodology of our study.

Figure 2.1: Overall methodology of the study [Source: Analysys Mason, 2013]



We carried out our analysis for the EU as a whole (EU-27) and for eight specific Member States (the Czech Republic, France, Germany, Italy, Poland, Spain, Sweden and the UK), to show the diversity of situations and outcomes compared to the pan-European perspective.

2 Formerly called wideband data transmission systems.

2.1.3 Step 1: Current spectrum usage

At the start of the project, our aim was to develop an accurate, quantitative understanding of current demand for spectrum usage across the EU-27 and in each of the selected Member States, broken down by category and frequency band. However, stakeholders were critical of the quantitative data available, and it quickly became clear that there is *no* common established view on current spectrum usage.

In the first workshop, we presented our initial estimates of current spectrum designations and usage for each category and per country. These estimates were mainly based on data from the European Communications Office Frequency Information System (EFIS), national frequency allocation tables (FATs) and the 2012 study on spectrum use by WIK-Consult,[3] supplemented with a few additional assumptions where needed. The workshop was intended to confirm that the EC and stakeholders had a common understanding of current demand for spectrum usage. However, we rapidly realised that this was not the case. In response to criticisms of our initial estimates, we requested more accurate data from relevant stakeholders, but unfortunately none of them were able to provide any quantitative inputs.

We explored some alternative methods of obtaining robust quantitative data, but without success. Therefore, we came to the conclusion that the existing data is not reliable enough to form a basis for accurate quantitative forecasts of future spectrum usage. Significant additional inputs and further work will be required, in particular, a thorough review of existing data on current spectrum usage and the provision of additional inputs from the EC, Member States and stakeholders as specified in the new Commission Implementing Decision (2013/195/EU): "*Data should be provided by Member States in the most consistent way possible, either through the European Communications Office Frequency Information System (EFIS), or directly to the Commission*"

Given this situation, we decided (in agreement with the EC) to take a *qualitative* approach, taking as a starting point the qualitative estimates provided in the WIK Study and allocate a range of quantitative usage values for each step on this scale. In the WIK Study, a rating scale was applied to each band, namely 0, 1, 2 and 3. We allocated a quantitative range of usage levels (i.e. a minimum and a maximum level) for each point on this scale, as follows:

- **0**: from 0% to 35% of the designated spectrum
- **1**: from 36% to 55% of the designated spectrum
- **2**: from 56% to 75% of the designated spectrum
- **3**: from 76% to 100% of the designated spectrum.

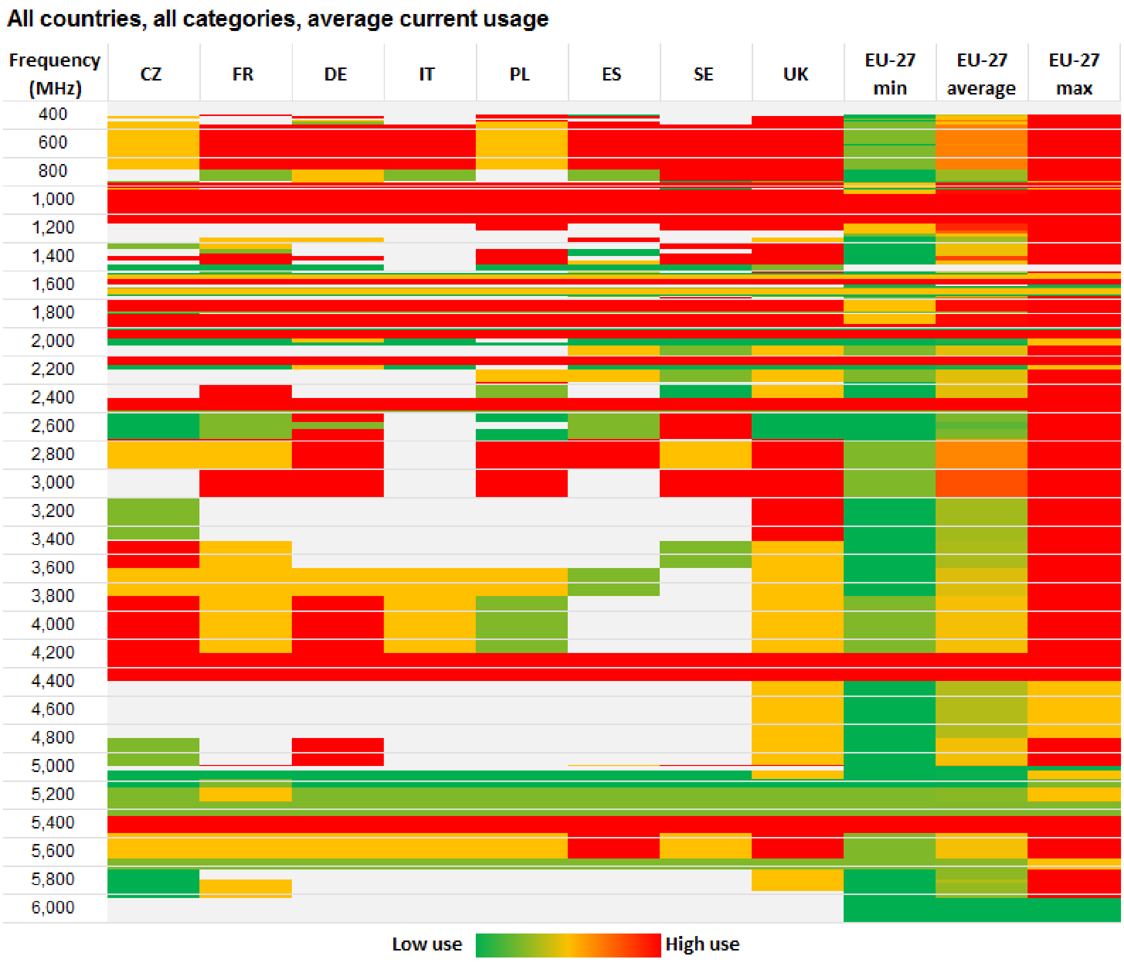
Given the wide range of usage levels covered by each of the four ratings (0–3), in order to decrease the level of inaccuracy in the starting point, in calculating future demand in each of the focus countries we based our calculations on the *average* current usage level corresponding to each rating. For example, in the inputs the usage rating 0 covers levels of usage ranging from 0% to 35%, but in our calculations this is normalised to 17.5%.

[3] WIK-Consult: *Inventory and review of spectrum use: Assessment of the EU potential for improving spectrum efficiency*, 2012

However, given the range in each rating, averages do not provide a full picture. Therefore, we also consider a *low* end and a *high* end of the range. For example, we also developed a view on the *minimum* and *maximum* current usage across all EU-27.

We present the results of our analysis of current spectrum usage in a series of 'heatmaps'. As an illustration, the heatmap, in Figure 2.2 below shows the current average spectrum usage, by study country and by usage category, across the entire frequency range (in steps of 10 MHz) from 400 MHz to 6 GHz. In addition, at the EU-27 level, the heatmap shows the minimum, average and maximum current usage.

Figure 2.2: Heatmap showing current average spectrum usage for all application categories [Source: Analysys Mason, 2013 based on WIK study]



We can draw the following conclusions from our analysis of current spectrum usage:

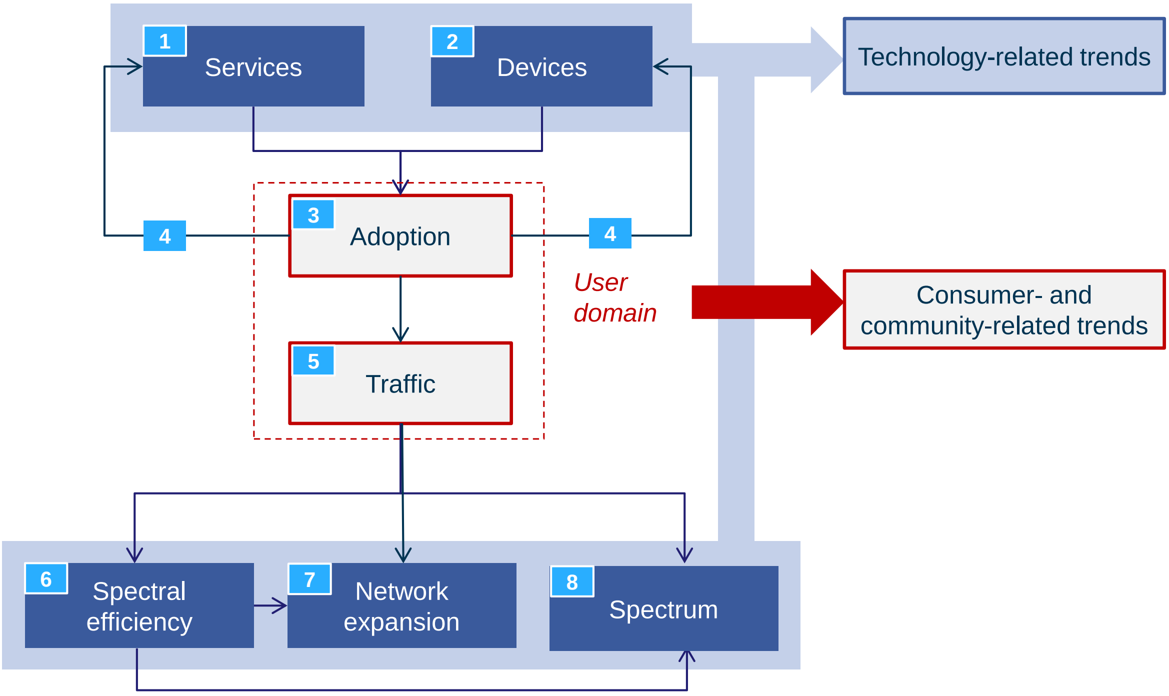
- Spectrum usage varies between the eight focus countries, and in particular current usage is quite high in some countries like the UK compared to other countries such as the Czech Republic. This diversity in the current situation in different Member States needs to be considered carefully when interpreting the European perspective. This diversity is also reflected in the difference between the minimum and the maximum usage in Europe as a whole.

- Some frequencies, such as the 2 GHz, 3.6 GHz and 3.8 GHz bands, appear to have a low usage in most of the focus countries, while other bands such as 1000 MHz and 5.4 GHz appear to have a high usage.
- There is lack of information relating to some frequencies, such as the 4.6 GHz, 4.8 GHz and 6 GHz bands, and also a limited amount of data for some countries like Italy, Spain or Sweden.

2.1.4 Steps 2, 3 and 4: Identification and assessment of trends

In the next three steps, we identified and assessed on an individual basis (a) technology-related trends, and (b) consumer- and community-related trends that affect spectrum usage, for each of the categories of usage over the next ten years. Our methodology for this is shown in Figure 2.3 below.

Figure 2.3: Methodology for identifying and assessing technology, consumer and community trends [Source: Analysys Mason, 2013]



1. Content producers, application developers, over-the-top (OTT) players, R&D and policy makers in some cases produce new and better services and content.
2. Device manufacturers develop more powerful devices which enable the provision of new services, improve the user experience (thus encouraging usage) and in some cases become symbols of social status.
3. End users and communities adopt services and devices.
4. Through users' adoption, the penetration of advanced devices encourages service take-up, which in turn improves the adoption of advanced devices.
5. Users' behaviour in terms of adoption of services and devices increases penetration and usage, and consequently traffic.
6. R&D-driven improvements in spectral efficiency for some technologies, which can reduce spectrum usage and allow spectrum release for other applications.
7. Operators and service providers expanding their networks as far as is financially viable.
8. New spectrum being made available (on a dedicated or shared basis) for each application, generating additional traffic.

We identified the main technology, consumer and community trends for each category of spectrum use that we and stakeholders believe are relevant in terms of future demand. We then assessed the impact that each trend will have on spectrum usage demand, taking into consideration the information gathered from our desk research, our interviews with stakeholders, and inputs from the workshops. We gathered quantitative evidence of underlying drivers likely to influence spectrum usage demand for each application, and requested supporting evidence from stakeholders where necessary. As there is uncertainty as to how many of these technology, consumer and community trends will develop, or be adopted, the impact assessments have been kept broad. We have used the following scale to rate the expected impact:

++ More than a 50% increase
+ Up to a 50% increase
= Limited impact
– Up to a 50% reduction
– – More than a 50% reduction

The impact assessment was made for three periods: short term (2012–2014); medium term (2012–2017); and long term (2012–2022). We believe that, despite the uncertainties regarding how many of these trends will develop, and the differing views of the various stakeholders, the results presented in the present report provide a solid foundation for the debate about the direction, scale and timing of demand for future spectrum usage.

2.1.5 Step 5: Demand for future spectrum usage

In this final step we combined all the trends to ascertain their collective effect (in qualitative terms) on spectrum demand in the short, medium and long term. We then applied these trends to the current usage levels and calculated, again on a qualitative basis, the expected future spectrum usage. We also developed minimum, average and maximum growth scenarios to cope with uncertainty in the data and different views on future growths. The results are presented as heatmaps: for each application category, we present heatmaps of spectrum usage across the whole EU-27 in 2014, 2017 and 2022, assuming (a) a minimum growth scenario, or (b) a maximum growth scenario. In addition, we give heatmaps for usage in the focus countries in 2022, based on an average growth scenario.

On the basis of this analysis, we identified areas in which future usage may exceed current designation, and over which period of time this may occur. Finally, we drew conclusions and developed recommendations for each category.

2.2 Trends influencing the demand for future spectrum usage

There are a large number of technology, consumer and community trends that will have an impact on the demand for future spectrum usage. On the one hand, the development of new spectrally efficient technologies will lead to an increase in spectrum capacity, though in some cases the migration to these new technologies will be made very gradually. Some technologies will be simulcast with the legacy technologies, so that for a certain period the demand for spectrum will actually be higher; and in some cases new technologies will even stimulate demand.

It is unlikely, however, that the development of technologies that are more spectrum-efficient will be enough to satisfy the growing demand arising from most of the consumer and community trends in the majority of the application categories. This situation is illustrated in Figure 2.4 below; as can be seen, in all categories except Fixed Links, Science and Meteorology, there is expected to be an increase of demand for future spectrum usage in the long term. The table shows the main technology and consumer and community trends associated with each category, along with our assessment of the impact of each group of trends on spectrum usage demand, and the key trends for each category.

We have also taken into account of specific demand for new spectrum where there is no usage today and a growth factor is therefore not applicable. It should be noted that future spectrum usage growth does not necessarily mean that there will be demand for spectrum in excess of spectrum designations: we explore the balance of future spectrum usage and designations in the following sub-section.

Figure 2.4: Overall assessment of the impact of technology, consumer and community trends on spectrum usage demand, by category [Source: Analysys Mason, 2013] Note: EU bands = Common bands across the EU-27. ST = short term (2012), MT = medium term (2017), LT = long term (2022)

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
AMCRN *960–1350* *2700–3100* *4200–4400* *5030–5150*	***Key factors driving spectrum usage demand for AMCRN****: high-speed broadband and live-TV services in-flight; the integration of RPAS into the civilian airspace; and advances in radiolocation services*		**=**	**=/+**	**+**
	Advances in radiolocation services	Technology	–/=	–/=	–/=
	Wireless avionics intra-communications	Technology	=	=	=
	Digital enhancements of analogue maritime mobile systems	Technology	=	=	=
	Direct air-to-ground communication	Technology	+	+	+
	Remotely piloted aircraft systems	Technology	+	+	+
	Digital enhancement of communications systems	Technology	=	=	=
	Growth in air passenger traffic	Consumer	=	=/+	=/+
	Growth in air freight traffic	Consumer	=	=/+	=/+
	Growth in sea freight traffic	Consumer	=	=	=/+
	High-speed broadband and live-TV services in-flight	Consumer	=	+	++

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
	Implementation of Single European Sky ATM Research (SESAR), 'the spectrum / technology' dimension of SES	Consumer	=	=/+	=/+
	Mandates to implement technology advances	Consumer	=	=/+	=/+
	Integration of RPAS into the civilian airspace	Consumer	=/+	+	++
Broadcasting *470–790*	***Key factors driving spectrum usage demand for broadcasting***: implementation and adoption of HDTV, UHDTV and 3DTV; and the technology migration path		**+**	**+/++**	**+/++**
	Development of alternative platforms to DTT	Technology	–/=	–	–
	New digital video formats	Technology	++	++	++
	Broadcasting encoding and transmission developments	Technology	=/+	=	– –
	Analogue switch-off / digital switchover	Technology	–/+	–	–
	Single-frequency network (SFN)	Technology	–/=	–	–
	Mobile TV / DVB-H	Technology	–	–	–
	Growing linear TV consumption	Consumer	=	=	=
	Growth in the number of TV channels	Consumer	+	=	=
	Adoption of DTT	Consumer	=	=	=
	Take-up of DAB	Consumer	=	=/+	=/+
	Implementation and adoption of HDTV/UHDTV/3DTV	Consumer	+	++	++
	Adoption of OTT and impact on DTT	Consumer	=	=	=
	Number of MUXs	Consumer	+	+	+
	Digital television switchover in CEE	Consumer	=/+	=	=
	Technology migration path	Consumer	+	++	++
Mobile *790–862* *880–915* *925–960* *1710–1785* *1805–1880* *1900–1980* *2010–2025* *2110–2170* *2500–2690* *3400–3600*	***Key factors driving spectrum usage demand for mobile***: development and adoption of more sophisticated devices; the extent of traffic being offloaded onto Wi-Fi networks (by both consumers and operators); and the launch of 3.5G/4G (LTE/LTE-Advanced) technologies		**+**	**+/++**	**+/++**
	Launch of LTE/LTE-Advanced	Technology	=/+	=	– –
	Growth in Wi-Fi offload	Technology	–/– –	–/– –	–/– –
	Development and adoption of more sophisticated devices	Technology	+	++	++
	Spectrum sharing and white spaces	Technology	–	–	–
	Femtocells	Technology	–	–	–
	In-building wireless	Technology	–/=	–/=	–/=
	WiMAX developments	Technology	–/=	–/=	–/=
	Launch of LTE/LTE-Advanced	Consumer	+	+	+
	Growth in Wi-Fi offload	Consumer	–	– –	– –
	Development and adoption of more sophisticated devices	Consumer	+	++	++

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage ST	Demand for future spectrum usage MT	Demand for future spectrum usage LT
	Adoption of data-hungry mobile applications	Consumer	++	++	++
	Increase of mobile data speeds	Consumer	++	++	++
	Adoption of M2M	Consumer	=	=	=
	Deployment of femtocells	Consumer	=/–	=/–	=/–
	Number of mobile network operators	Consumer	=	=/–	=/–
	Spectrum sharing and white spaces	Consumer	=	–	–
Defence *406–410* *430–433* *435–446* *446–450* *870–876* *915–921* *1300–1350* *1518–1525* *2025–2110* *2200–2400* *3100–3410* *4400–5000* *5150–5350*	***Key factors driving spectrum usage demand for defence***: growth in the number of connected devices and in the amount of information exchanged; development and take-up of unmanned aeronautical systems; and limited changes in positioning and navigation technologies		**=**	**+**	**++**
	Growth in information exchange (enhanced connectivity)	Technology	++	++	++
	Potential compression benefits from new technologies (i.e. detection and radar improvements)	Technology	=	=	=
	Positioning and navigation	Technology	=	=	=
	Information acquisition	Technology	+	+	+
	Growth in activity in the Defence sector	Consumer	=	+	+
	Growth in information exchanged (enhanced connectivity)	Consumer	=	+	++
	Increase in unmanned aeronautical systems	Consumer	=	+	++
	Potential compression benefits from new technologies	Consumer	=	= / +	+
	Potential of freeing spectrum allocated to Defence	Consumer	=	=	=
	Increase in satellite use with civil and governmental assets	Consumer	+	+	++
	Potential to switch to commercial services/operators	Consumer	=	=/+	=/+
Fixed links *1350–1400* *1427–1452* *1492–1525* *1700–1710* *2025–2110* *2200–2290* *3800–4200* *5925–6425*	***Key factors driving spectrum usage demand for fixed links***: the degree of substitution by fibre networks; and the migration of fixed links to higher frequencies		**=/–**	**–**	**– –**
	Microwave to fibre substitution	Technology	– –	– –	– –
	Higher-frequency links	Technology	– –	– –	– –
	NLoS/QLoS backhaul	Technology	+	+	+
	Improved modulation techniques	Technology	–	–	–
	Use of XPIC	Technology	–	–	–
	Other technology advances	Technology	=	=	=
	Zero-footprint advances	Technology	=	=	=
	Microwave to fibre substitution	Consumer	= / -	= / -	- / --
	Demand for higher-frequency links	Consumer	- / --	- / --	- / --
	Deployment of new mobile stations	Consumer	+	+/++	+/++
	Take-up of services that require low latency	Consumer	=	=	=

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage ST	MT	LT
ITS *5795–5815* *5875–5905*	***Key factors driving spectrum usage demand for ITS***: the development and take-up of new ITS applications		**=**	**+**	**++**
	New ITS applications	Technology	=	+	+
	Vehicle-to-vehicle communications	Technology	+	+	+
	Rail applications	Technology	=	=	=
	New ITS applications	Consumer			
	Traffic and freight management	Consumer	=/+	+	+
	Integration vehicle-infrastructure	Consumer	=	+	++
MET *401–406* *1675–1710* *5350–5650*	***Key factors driving spectrum usage demand for MET***: maintain current spectrum designations for meteorology due to their specific physical properties		**=**	**=**	**=**
	Radar improvements	Technology	=	=	=
	Satellite services	Technology	=	=	=
	Global Observing Systems (GOS)	Consumer	=	=	=
	WIGOS	Consumer	=	=	=
	Harmonisation	Consumer	=	=	=
PMR/PAMR *406–433* *435–470* *870–880* *915–925*	***Key factors driving spectrum usage demand for PMR***: the introduction and take-up of smart grid and smart metering applications		**=/+**	**+**	**+**
	Digital replacements	Technology	–/=	–/=	–/=
	Smart grid and smart metering	Technology	++	++	++
	Smart grid and smart metering	Consumer	=/+	+	+
	General PMR/PAMR	Consumer	=	=	=/+
	ECTS and GSM-R replacement	Consumer	=	=	=
PMSE *470–790* *1785–1800* *2025–2110* *2200–2400* *3100–3400*	***Key factors driving spectrum usage demand for PMSE***: the type and number of events; the type of equipment; the increase in the amount of equipment per event; and the adoption of HD and 3D cameras		**+**	**+**	**+**
	Adoption of HD and 3D cameras	Technology	++	++	++
	Digital microphones	Technology	=	=	=
	Mobile broadcast systems	Technology	+	+	+
	Higher-frequency wireless cameras	Technology	=	=	=
	Adoption of HD and 3D cameras	Consumer	+	+	++
	Type and number of events	Consumer	+	+	+
	Type of equipment and growth	Consumer	+	+	+
	Increase in the number of equipment per event	Consumer	+	+	++
PPDR *3100–3400* *4940–4990*	***Key factors driving spectrum usage demand for PPDR***: increasing demand for data-rich applications; and the potential for PPDR services to make use of commercial services and networks		**=**	**+**	**++**
	TETRA 2 (TEDS)	Technology	=/+	+	+
	PPDR high-speed data networks	Technology	=/+	+	++

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
	Use of commercial networks	Technology	–/=	–/=	–/=
	Demand for data-rich applications	Consumer	=	+	++
	Growth in security requirements	Consumer	=	+	+
	Potential to switch to commercial services	Consumer	=	=	=
	Level of adoption of new technologies	Consumer	=	=	=
Science *1400–1427* *1610–1614* *1661–1675* *2290–2300* *2690–2700* *4940–5000*	***Key factors driving spectrum usage demand for Science***: maintain current spectrum designations for meteorology due to their specific physical properties		**=**	**=**	**=**
	More powerful back-end processing	Technology	=	=	=
	Very long baseline interferometry	Technology	=	=	=
	Allocation demand	Consumer	+	+	+
	Usage demand	Consumer	=	=	=
Satellite *1164–1215* *1525–1610* *1614–1661* *1980–2110* *2170–2290* *2484–2500* *3600–4200* *5000–5030* *5875–6425*	***Key factors driving spectrum usage demand for Satellite:*** the increase in backhaul services within the C-band as well as the surge in demand for the S-band		**=/+**	**+**	**+**
	Galileo navigation system	Technology	=/+	=/+	+
	High-speed satellite broadband	Technology	=	=	=
	Mobile satellite services	Technology	=	=	=
	L-band MSS	Technology	+	+	+
	Ku-band FSS	Technology	=	=	=
	Satellite L-band DAB	Technology	–	–	–
	M-LNB	Technology	=	=	=
	L-Band	Consumer	=	=	=
	S-band	Consumer	=	+	+
	C-band	Consumer	=/+	=/+	=/+
	Amateur satellite	Consumer	+	+	+
SRDs *433–435* *863–870* *1785–1800* *1880–1900*	***Key factors driving spectrum usage demand for SRDs***: the growth of RFID devices and growth in different applications		**+**	**+**	**+**
	Technology developments	Technology	–	–	–
	Harmonisation of modulation techniques	Technology	=	=	=
	Growth in the use of SRDs for medical apps	Technology	=/+	=/+	=/+
	Growth of RFID devices	Technology	+	+	+
	Geo-location databases	Technology	–	–	–
	Growth of alarms	Consumer	+	+	+
	Growth of home and building automation	Consumer	+	+	+
	New requirements in the automotive industry	Consumer	+	+	+
	Geo-location databases	Consumer	–	–	–
	Take-up of automotive SRDs	Consumer	+	+	+
	Growth in the use of SRDs for medical apps	Consumer	+	+	+
	Harmonisation of modulation techniques	Consumer	=	–	–

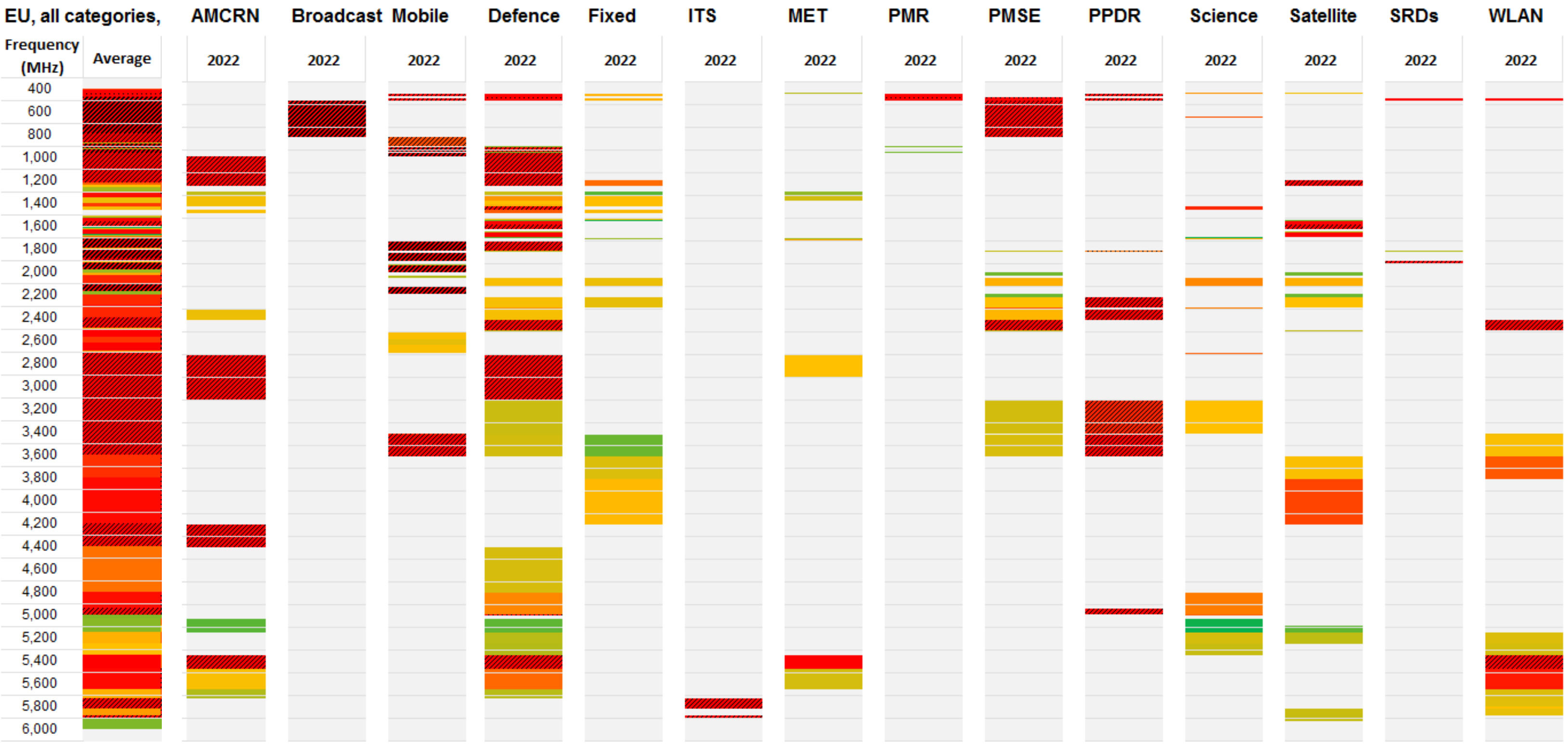
Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
WLAN *2400–2484* *3400–3410* *5150–5350* *5470–5875*	***Key factors driving spectrum usage demand for WLAN*: the continued growth in Wi-Fi network reach and user adoption**		**+**	**+**	**+**
	Growth in the number of hotspots	Technology	+	+	+
	New Wi-Fi standards	Technology	+	+	+
	Wi-Fi roaming (offloading)	Technology	+	+	+
	Growth in the number of hotspots	Consumer	+	+	+
	Continued growth in Wi-Fi network reach and user adoption	Consumer	++	++	++
	Rural fixed wireless access	Consumer	=	-	-
	Release of spectrum designated to WiMAX	Consumer	=	=	=/-

2.3 Future spectrum usage

2.3.1 Future usage by category and band

Figure 2.5 overleaf shows a heatmap of spectrum usage in 2022 across the whole EU-27, broken down by application category. This is based on average current spectrum usage and the average growth scenario. As can be seen, there are key regions of spectrum that are likely to experience demand in excess of 100% of the designated band by 2022 (shown in the figure as red with diagonal shading). Some application categories, such as AMCRN, exhibit high usage across a larger number of bands than others.

Figure 2.5: Heatmap showing spectrum usage in 2022, by application category and total, based on average current usage and the average growth scenario [Source: Analysys Mason, 2013]



The main frequencies bands where future spectrum demand usage is above 100% of the current designation are:

- 400–1200 MHz, due to broadcasting, mobile and possibly defence
- 1700–2200 MHz due to mobile and possibly defence
- 2700–3100 MHz due to AMCRN, PPDR and possibly defence
- 4200–4400 MHz due to AMCRN
- 4900–5000 MHz due to PPDR
- 5750–5850 MHz due to ITS.

There are, conversely, areas of the spectrum that show less than 100% usage of designation by 2022 in this scenario, notably:

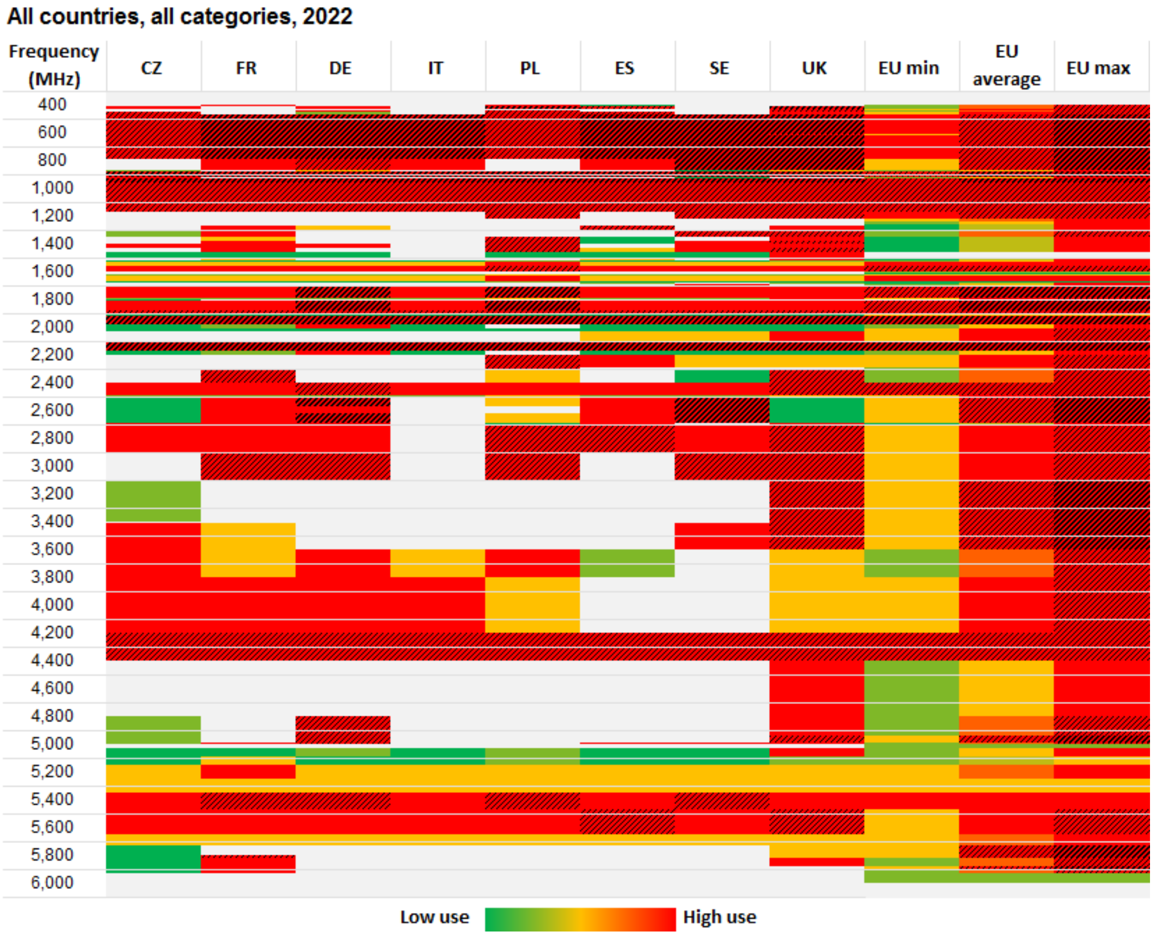
- 1200–1400 MHz where AMCRN, defence, fixed and MET may benefit
- 2000–2100 MHz, where a number of categories may benefit
- 3600–4100 MHz, where fixed and satellite may benefit
- 4400–4900 MHz, where defence is the only application present
- 5000–5400 MHz, where a number of categories could benefit
- 5650–5750 MHz, where a number of categories could benefit
- 5850–6000 MHz, where ITS and satellite may benefit.

2.3.2 Future usage by country

Each of the focus countries presents a different picture of spectrum usage, and there are therefore significant differences in future spectrum demand. Figure 2.6 shows a heatmap of spectrum usage in 2022 (for all application categories) in each of the eight focus countries. It also shows the minimum, average and maximum usage across the whole EU-27. As can be seen, in some regions of the spectrum there are significant differences between countries, while in other regions the picture is more homogeneous:

- **Sub-2 GHz bands**: usage is fairly homogeneous across the eight countries.
- **2–3 GHz region**: there is a more mixed range of usage across the eight countries, particularly in 2500–2700 MHz, where for example the Czech Republic and the UK show low usage whereas Sweden and the EU average show a usage above 100% of current designation.
- **3–5 GHz region**: the picture here is also fairly heterogeneous; for example, usage in 3600–3800 MHz ranges from low in the EU minimum case and Spain, to over 100% in the EU maximum case.
- **5–6 GHz: region**: usage is fairly homogenous across the eight countries.

Figure 2.6: Heatmap showing spectrum usage in 2022 in the focus countries, average growth, and the EU-27 minimum, average and maximum usage [Source: Analysys Mason, 2013]



2.4 Overall conclusions, recommendations and potential next steps

Overall, even though we have not been able to estimate quantitatively the demand for future spectrum usage, we believe that our results provide a solid base to inform future spectrum usage and needs, and to highlight areas that require further work to improve the accuracy of the results. In particular, we believe that the results of this study are very useful to inform the debate about the direction, scale and timing of future spectrum usage demand, together with the key drivers that will determine this demand. However, there are some issues that need further work, and some actions to be taken.

- There are significant differences in spectrum usage across the focus countries, both currently and in the future. This is also shown by the differences between the minimum and maximum usage in the EU-27 as a whole. The main differences are between 2 GHz and 5 GHz frequency ranges.
- For most application categories there is significant uncertainty regarding the impact on spectrum demand of the different technology, consumer and community trends, particularly in the longer term. Many research houses that provide forecasts for the different trends do not provide data for the long term. Moreover, estimates vary widely between the various research houses, and their forecasts are adjusted annually.

- There are also some uncertainties regarding the designation of some spectrum bands in some countries, which make it difficult to accurately estimate the demand for future spectrum usage. One example is the possible designation of spectrum in the 700 MHz band (in the 694–790 MHz range) to mobile services.
- Future spectrum usage – across most frequencies – will increase significantly over the next 10 years. However specific nature of the congestion problem is completely different in the short term, medium term and long term. Generally, congestion problems begin to appear mainly in the medium term.
- Since for most categories demand for spectrum is increasing, more sophisticated sharing of spectrum is increasingly important – for example based on white spaces. It is therefore important to invest more time and resources in identifying and developing possibilities for spectrum-sharing.
- It is important to note that many bands are not exclusively used by one type of application, but are often shared with other categories. In theory, therefore, clearing this spectrum for other users would require the sharing services to vacate the spectrum as well. For this reason, many of the results of any calculations will tend to be lower than may be necessary in reality.
- For some categories, spectrum may also not be used on a regular basis, or only in limited geographical areas – for example, some of the spectrum allocated for defence use. This may raise the possibility for some of this spectrum to be made available for use by other categories under carefully designed conditions.
- Some categories are interrelated, and therefore in some cases demand by one category will reduce demand by another. For example, the spectrum demand for both mobile and Wi-Fi is driven mainly by the growth in on-demand video and audio-visual services on tablets, smartphones and other devices. In such cases, satisfying demand from one category is likely to be at the detriment of the other category – and different stakeholders will have different perspectives on how such competing demands should be met.
- Some actions that are currently being discussed to reduce future congestion problems have not been included in our qualitative estimations – for example, there are some studies ongoing in Europe into extending SRD bands above 870 MHz.
- Existing data on current spectrum *usage* is not reliable enough to form a basis for accurate quantitative forecasts of spectrum *usage* demand. To remedy this, it is important that Member States improve their knowledge of current spectrum usage and make this data publicly available.
- There are concerns about the 14 application categories and how these should be categorised and demand estimated. It is important to be clear about which applications are included under each category, and the exact mapping onto EFIS layers, in order to minimise duplication or overlaps.
- We would like to note that the scope of this study does not include any assessment of the societal and economic benefits of spectrum and the various applications that use it. We have not taken into account any environmental issues.

3 Context, objectives and work carried out

3.1 Context and objective of the study

Spectrum is a key and scarce public resource that is essential to many sectors and services. One goal of public policy across the European Union (EU) is to maximise the economic and social value derived from multiple and diverse potential uses of spectrum. To support this, on 15 February 2012, the European Parliament and Council approved the first Radio Spectrum Policy Programme (RSPP). The general objective of the RSPP is to set out policy orientations and objectives for the strategic planning and harmonisation of the use of spectrum in Europe. In particular, Article 9 of the RSPP establishes the need to develop an inventory of existing uses of spectrum in order to identify bands where efficiency of spectrum uses could be improved.

In order to achieve these objectives, the Commission will need to adopt implementing acts, with the assistance of the Radio Spectrum Committee (RSC), setting out practical modalities and uniform formats for the collection and provision of data by Member States on their spectrum uses, in particular for spectrum between 400 MHz and 6 GHz. In particular, Point 4 of Article 9 of the RSPP establishes that "*the Commission shall conduct the analysis of technology trends, future needs and demand for spectrum in accordance with the implementation acts.*"

It is in this context that the European Commission, DG Communications Networks, Content and Technology ('the EC' or 'the Commission') hired Analysys Mason Limited ('Analysys Mason') to support the Commission in the implementation of Article 9, by analysing technology trends and assessing future needs and demand for spectrum usage. In particular, the primary objective of the present study is to assess incremental usage demand for particular categories of spectrum (e.g. demand for mobile spectrum) over the next ten years in the EU-27, within the frequency range from 400 MHz to 6 GHz only.

The present document is the Final Report of the study *Analysis of technology trends, future needs and demand for spectrum in line with Art. 9 of the RSPP* (SMART 2012/0005).

3.2 Tasks undertaken

The scope of the study was defined as comprising the following tasks:

- Propose an appropriate methodology that
  - takes into account the Radio Spectrum Policy Group's (RSPG) opinion on the review of spectrum
  - considers relevant aspects that may have an impact on the demand for spectrum, such as economic conditions, technology trends and policies that create demand for spectrum
  - considers the different requirements from various user communities
  - considers European diversity and the differences between Member States.

- Assess the relevant technology trends which influence the demand for spectrum (over a period of ten years), including:
  - all aspects of technology developments
  - relevant research and development (R&D) activities
  - any promising technology in need of spectrum, or leading to a more efficient use of spectrum.
- Conduct an analysis of consumer-driven demand for spectrum addressing both private and public uses
  - *private use*, mostly by commercial players, both licensed and licence-exempt, such as mobile network operators (MNOs), and commercial TV and radio broadcasters
  - *public use*, by sectors fulfilling objectives that are in the public interest, such as public-sector broadcasters and public radio, security and safety, academic and scientific.
- Conduct an analysis of future needs and demand for spectrum from user communities, in particular
  - manufacturers of wireless equipment
  - various public-sector users including safety, security and defence (to the extent these are not covered in the previous task).
- Examine previous findings and develop recommendations in relation to future needs and demand for spectrum usage and potential measures to accommodate them, in particular
  - from a technical point of view, whether or not the demand can be accommodated within the frequency range from 400 MHz to 6 GHz over the next ten years
  - what amount of spectrum and which frequency bands would be best suited for the needs and demands identified (this analysis is subject to the limitations and uncertainty regarding current estimations of spectrum usage)
  - which measures need to be implemented to accommodate such needs and demand for spectrum (e.g. change of allocations, harmonisation) – commenting on potential alternatives to allocate future growth in the cases where demand for future spectrum usage could go beyond existing designated spectrum
  - which current uses are likely to be phased out.

3.3 Structure of the report

This report presents the results and recommendations from the study. It is laid out as follows:

- **Section 4** describes the methodology we have followed, and discusses certain issues with the data available.
- **Section 5** provides our analysis of the technology trends which are likely to influence the demand for future spectrum usage; these are considered under 14 categories of spectrum use.
- **Section 6** presents our view of the trends in consumer- and community-driven demand for each category of spectrum, and assesses the impact they are likely to have over the next ten years.
- **Section 7** provides our recommendations of potential measures to accommodate the future demand identified for each category of spectrum use.
- **Section 8** provides our main conclusions for this study.

In addition, the following supplementary materials are appended to this report as annexes:

- **Annex A**: Other existing studies consulted for this report
- **Annex B**: Detailed Long Term Evolution (LTE) technology trends
- **Annex C**: Mapping of Inventory Application Groupings onto EFIS Applications (Level 2)
- **Annex D**: Glossary of terms.

4 Methodology used

This section describes the methodological approach we have taken for the analysis of technology and consumer and community trends, to be able to assess future demand usage for the various categories of spectrum. We begin by clarifying the principles we have followed, and discussing some major limitations in the data available to us and our approach to dealing with this issue.

4.1 Methodological principles and issues with data

4.1.1 Future spectrum *demand* versus future spectrum *designation*

The objective of the present study is to assess incremental *usage demand* for particular categories of spectrum (e.g. demand for mobile spectrum) over the next ten years in the EU-27, within the frequency range from 400 MHz to 6 GHz only. It does not aim to forecast any changes that may be made to the spectrum *designated* to those categories of use, although such designation could be informed by future spectrum usage needs.

In some cases, the forecast spectrum usage demand may exceed the amount of spectrum that is currently designated for a particular use. For example, Figure 4.1 below shows the spectrum designated in the UK for use for mobile telecoms applications (880.1–914.9 MHz, a total bandwidth of 34.8 MHz). Currently, a certain amount of this spectrum may be unused (the dark blue area in the figure). By 2022, there is expected to be an increase in the spectrum usage demand of mobile operators for this band (the red area in the figure). It is this incremental usage demand that is the focus of the present study. As a result of this additional demand, the total demand may still be *less* than the 34.8 MHz designated (outcome (a) in the figure), or it may be *greater* than this amount (outcome (b)).

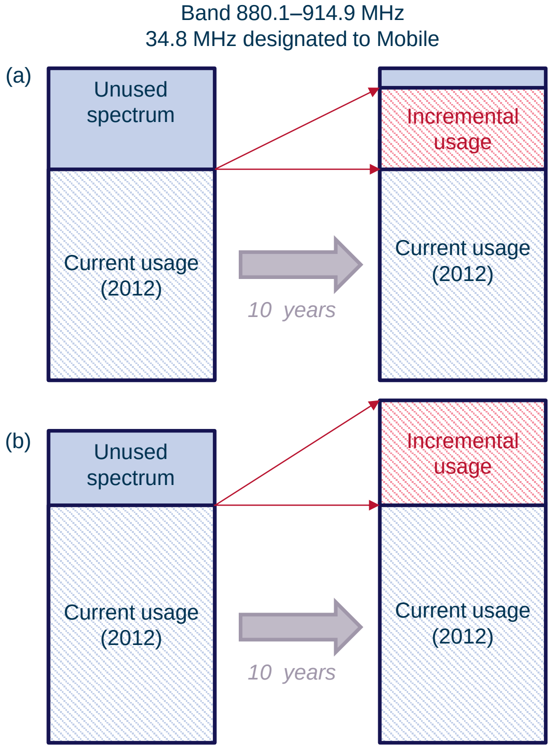


Figure 4.1: Illustrative example of the main objective of this project [Source: Analysys Mason, 2013]

As explained later in this section, we have estimated both current and future levels of spectrum usage demand in relative terms as a proportion (percentage) of the amount of spectrum currently designated to the particular category; we are not directly concerned with the absolute amounts of designated spectrum per se.

4.1.2 Definitions of the categories of spectrum use

Our analysis assesses levels of spectrum usage demand broken down into the various types of application groupings that use the spectrum. In order to be consistent with the Commission Implementing Decision (2013/195/EU)[4] and the study undertaken by WIK-Consult GmbH (together with Aegis Systems, Plum consulting and IDATE) as part of the first RSPP,[5] ('the WIK study'), we have used the same 14 application categories as were defined on pages 16 and 17 of that report:

1. Aeronautical, maritime and civil radiolocation and navigation systems (AMCRN)
2. Terrestrial broadcasting (Broadcasting)
3. Cellular/BWA (Mobile)
4. Defence systems (Defence)
5. Fixed links (Fixed)
6. Intelligent transport systems (ITS)
7. Meteorology (MET)
8. Private mobile radio/public access mobile radio (PMR/PAMR)
9. Programme making and special events (PMSE)
10. Public protection, disaster relief (PPDR)
11. Radio astronomy (Science)
12. Satellite systems (Satellite)
13. Short-range devices (SRDs)
14. WLAN/RLAN (WLAN).[6]

In order to enable the reader to better understand what uses are covered by each category, we have included in Annex C a table mapping these 14 categories onto the existing EFIS[7] level 2 applications, as shown in Table 47 of the WIK Study.

During this project we have received several comments from stakeholders regarding these application categories, and how different applications should be categorised. There may, indeed, be reasons for changing the definitions of some of these categories, but for consistency with the Commission Implementing Decision (2013/195/EU), we have used exactly the same definitions. We note that the changes in applications and categories suggested by stakeholders would not significantly affect the results of our study.

4 Commission Implementing Decision of 23 April 2013 defining the practical arrangements, uniform formats and a methodology in relation to the radio spectrum inventory established by Decision No 243/2012/EU of the European Parliament and of the Council establishing a multiannual radio spectrum policy programme (notified under document C(2013) 2235). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32013D0195:EN:HTML

5 WIK-Consult on behalf of the European Commission (2011), *Inventory and review of spectrum use: Assessment of the EU potential for improving spectrum efficiency (SMART 2011/0016)*. Available at https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/cion_spectrum_inventory_executive_summary_en.pdf

6 Formerly called wideband data transmission systems.

7 EFIS = European Communications Office Frequency Information System.

4.1.3 Lack of accurate data regarding current spectrum usage

As the first step in this project, we needed to develop a good understanding of current demand for spectrum usage across the EU-27 and in each of the selected Member States, broken down by category and frequency band. However, from the start, stakeholders were critical of the quantitative data available, and it quickly became clear that there is *no* common established view on current spectrum usage.

We presented the preliminary results of our assessment to stakeholders during three workshops, and encouraged them to provide feedback and further inputs to ensure that the information gathered was as complete and accurate as possible. In our first workshop, held in December 2012, we presented initial estimates of current spectrum designations and usage for each category and per country. These estimates were mainly based on data from the EFIS system, national frequency allocation tables (FATs) and the WIK Study, supplemented with a few additional assumptions where needed. The main objective was to confirm that the EC and all stakeholders had a common understanding and view on demand for current spectrum usage. However, we rapidly realised that this was not the case. In response to criticisms of our initial estimates, we requested more accurate data from relevant stakeholders, but unfortunately none of them were able to provide any quantitative inputs.

Obviously, this was not ideal for our study, as it undermined our ability to develop accurate quantitative estimates of demand for future spectrum usage. In an attempt to address this, we sought to develop an acceptable quantitative view of current spectrum usage based on the existing data. To do this, we went through a two-step process: first, we extracted data from the EFIS database for the countries and bands being studied; second, we mapped this very granular data onto the 14 usage categories. These two steps are described below.

Step 1: Extract data from the EFIS database

EFIS contains a database that lists frequency bands and specifies their corresponding *allocations* in each Member State; it also has a database that specifies the *applications* of each band. The definitions of these terms are given by EFIS as follows:[8]

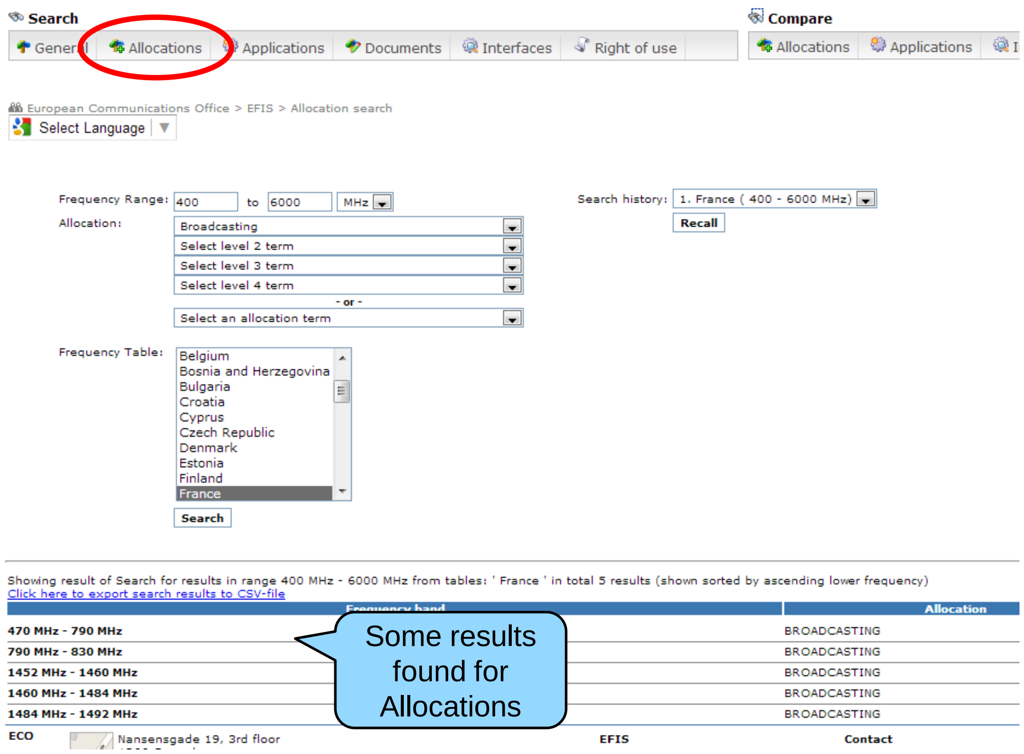
> *‘**Allocations**’: specifies the radio services authorised by an individual administration under their National Table of Frequency Allocations (NFTAs). The national allocations may differ from those in the Radio Regulation (RR).*
>
> *‘**Applications**’: specifies, based on some national inventory the “applications in use” within a country and using the three layers EFIS terminology defined in Annex 2 of ECC Decision (01)03 [15].*

8 CEPT Report 46 (2013), *Report from CEPT to the European Commission in response to the Mandate on inclusion of information on rights of use for all uses of spectrum between 400 MHz and 6 GHz* Available at http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep046.pdf

Moreover, according to ECC Decision (01)03 [p.10], "*the List of Searchable Applications is complementary to the List of Radio Services in the ITU RR and it is meant to describe the actual utilisation of the frequency bands*".[9] In other words, the List of Radio Services in the ITU Radio Regulations gives the regulatory framework, while the List of Searchable Applications gives the actual use.

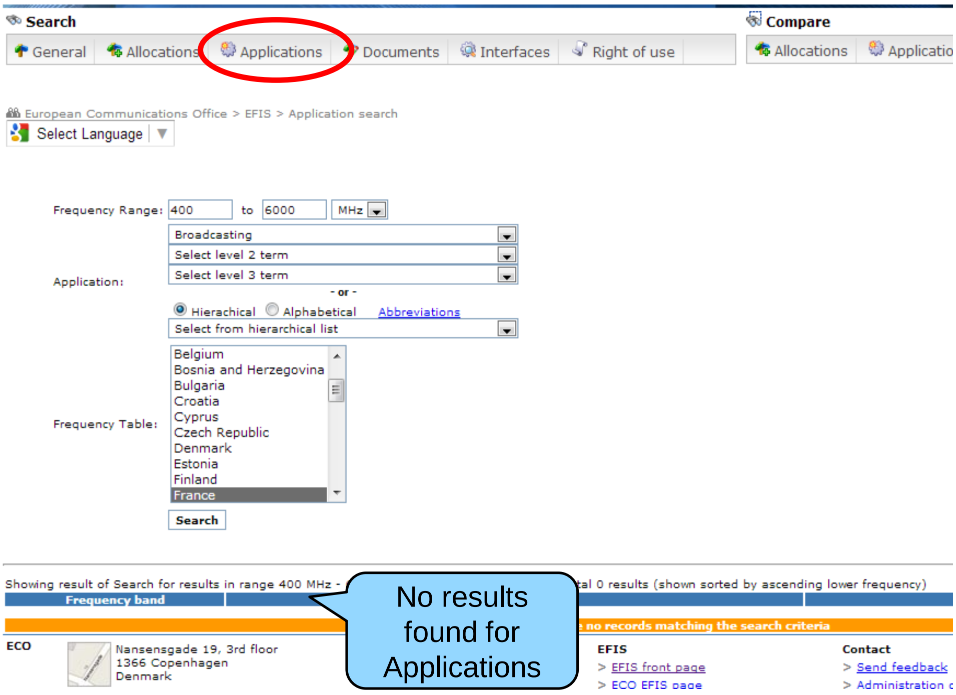
One of the main issues we discovered at this stage was the potential differences in the two sets of data (i.e. allocations *versus* applications). It was not clear whether or not the two databases are in fact complementary in a coherent manner, and if so, to what extent. To illustrate this, the graphics in the figures below show the same search being carried out on the allocations and applications databases. In each case the search was for broadcasting designations in France within the frequency range from 400MHz to 6GHz. As can be seen, the results from both searches are very different. This incoherence presents the largest problem in obtaining accurate and reliable data for current spectrum designation and usage.

Figure 4.2: Example: EFIS results for broadcasting 'allocations' in France [Source: Analysys Mason, 2013; EFIS, 2013]



9 http://www.erodocdb.dk/docs/doc98/official/pdf/ECCDec0103.pdf

Figure 4.3: Example: EFIS results for broadcasting 'applications' in France [Source: Analysys Mason, 2013; EFIS, 2013]



In order to develop a common view on current spectrum usage that is coherent with other studies, the decision was made to use the EFIS *applications* database, as this was used in the WIK Study.

Step 2: Map EFIS data onto the 14 usage categories

Having obtained country-specific data from EFIS on the applications actually in use in each band, we needed to map this onto the 14 application categories used in our analysis. EFIS contains data on three 'layers' of applications.[10] As regards layer 1 applications, whilst some of the EFIS applications match up to our categories, some of them span more than one category. A more granular mapping was necessary, and to achieve this we used the mapping from EFIS layer 2 applications onto our 14 categories that were given in the Commission Implementing Decision (2013/195/EU).[11] The figure below shows an example of the mapping between EFIS applications and the usage categories used in this report. By using this comprehensive mapping of EFIS applications onto the usage categories, the data was summed to create totals for each category and country.

10 Defined in Annex 2 of ECC Decision (01)03 [15].

11 Source: Table 47 of the WIK Study. This is reproduced in Annex C of the present report.

Figure 4.4: Example of mapping of EFIS applications onto our 14 usage categories [Source: The WIK Study]

EFIS Layer 1	EFIS Layer 2	Application Grouping for Inventory efficiency analysis
Aeronautical	Aeronautical communications	Aeronautical, Maritime and Civil Radiolocation / Navigation Systems (AMCRN)
	Aeronautical navigation	
	Aeronautical surveillance	
	Aeronautical emergency	
	Aeronautical telemetry	
	Aeronautical telecommand	
	Aeronautical telemetry/telecommand	
	Satellite navigation systems	
Broadcasting	Broadcasting (terrestrial)	Broadcasting (terrestrial)
	Broadcasting-satellite receivers	Satellite systems (civil)
	SAP/SAB and ENG/OB	PMSE
Fixed	Point-to-Multipoint	Fixed Links
	Point-to-Point	
	BWA	BWA / Cellular
	MFCN	
Defence systems	Aeronautical military systems	Defence Systems
	Land military systems	
	Maritime military systems	
	Meteorological aids (military)	
	Radiolocation (military)	

However, at this stage it was clear that the data from EFIS had some limitations; most of these had already been mentioned in the WIK Study. The figure below shows a sample of results with some problematic data points highlighted.[12]

Figure 4.5: Spectrum designations by category and country [Source: EFIS application database, 2013; Analysys Mason, 2013]

	CZ	FR	DE	IT	PL	ES	SE	UK
AMCRN	1,525	4	1,263	1,421	1,682	1,122	2,857	4,781
Broadcast	480	0	28	286	200	72	28	328
Mobile	1,743	639	1,158	544	334	1,250	1,468	1,094
Defence	0	4,594	3,260	0	3,704	2,262	2,651	3,465
Fixed	1,148	669	736	1,397	1,301	906	171	1,812
ITS	113	48	98	0	20	129	70	58
MET	432	0	136	300	53	107	88	833
PMR	18	17	45	0	22	72	37	81
PMSE	1,244	445	917	709	37	209	320	1,309
PPDR	0	0	143	0	2	0	0	141
Science	146	0	315	0	220	20	134	58
Satellite	1,549	1,208	2,290	610	261	633	1,187	1,515
SRDs	294	7,223	2,089	403	299	1,764	358	7,222
WLAN	539	539	489	409	455	489	455	699

12 The abbreviations for the usage categories were explained in Section 4.1.2 above.

As can be seen from the figure above:

- Some data is clearly wrong – for example, the amount of spectrum designated for AMCRN in France is given as 4MHz, which is quite obviously incorrect, as can be seen from the values for the other countries.
- Many categories have no data, such as Defence in Italy and the Czech Republic.
- In some cases there are unrealistic differences between countries within the same category – e.g. Satellite in Germany is specified as using 2290 MHz, a much higher band than in the other countries.

It should also be noted, as it is quite visible from this data, that for PPDR (public safety) it may be better to start at 380 MHz instead of 400 MHz. With so many countries using 380–400 MHz for these services, it skews the picture to miss such an important band.

Another issue not to use the data included in EFIS is that it provides data on allocations, designations and right of use but it does not provide data on spectrum usage.

4.1.4 Decision to use *qualitative* estimates for this study

Faced with the issues described above, we came to the conclusion that the existing data is not reliable enough to form a basis for accurate *quantitative* forecasts of spectrum usage demand. Such quantitative analysis would require a thorough review of existing data on current spectrum usage and the provision of additional inputs from the EC, Member States and stakeholders. In fact, what was supposed to be an input to our study is a major task in itself which will have to be dealt with separately in the future, as it is clearly outside the scope and mandate of the present study.

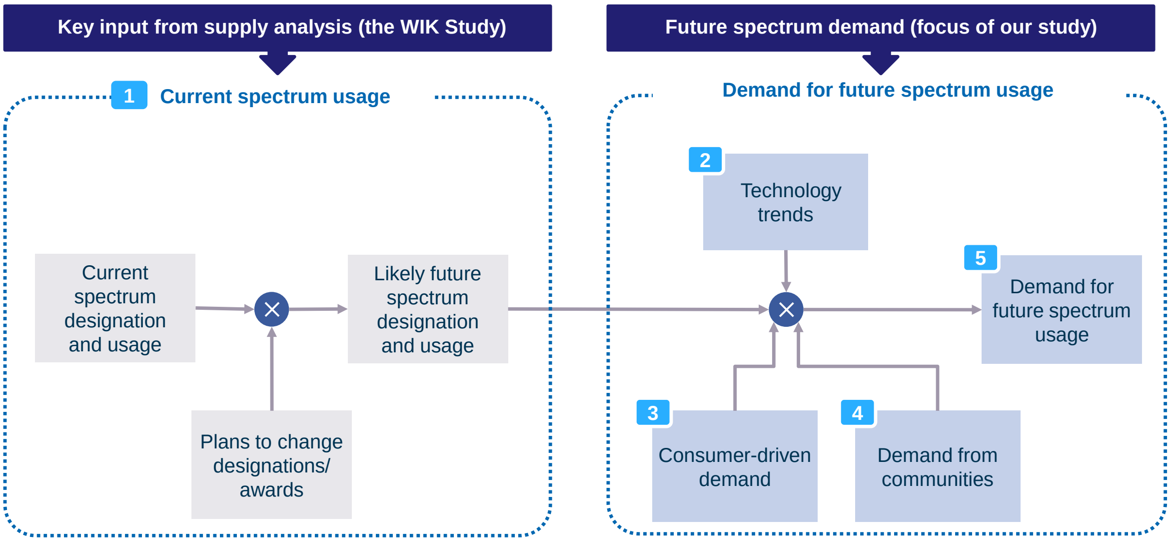
Regretfully, therefore, we decided (in agreement with the EC) to take a *qualitative* approach, taking as a starting point the estimates provided in the WIK Study. That study rates the level of usage of each band on a scale from 0 to 3 (where [0] means not in use or not applicable; [1] denotes low usage; [2] indicates medium usage; and [3] means high usage), and we have allocated a range of quantitative usage values for each step on this scale (as described in Section 4.3 below). In our final forecasts, we assess the impact of the trends analysed, in terms of a five-point scale ranging from -- (more than a 50% reduction in demand) to ++ (more than a 50% increase).

This approach does not allow the development of full quantitative forecasts of future spectrum usage demand, and involves a significant degree of uncertainty in our results. We recognise that this methodology may be subject to some criticism, but we believe that it would be highly misleading to offer quantitative forecasts when there is insufficient robust data to justify them. Nevertheless, we believe this study is still useful to inform debate, focusing on relative figures more than absolute values, and providing an understanding of the factors that will lead to different scenarios of future spectrum usage. Finally, we understand this is a dynamic process and much of our work and findings can be reused to estimate future spectrum usage needs more accurately once a common view of current spectrum usage exists.

4.2 Overview of the methodology followed

The overall methodology of this study was broken down into five distinct steps, as illustrated in Figure 4.6. We carried out our analysis for the EU as a whole (EU-27), and for eight specific Member States, agreed with the Commission at the beginning of this project (Czech Republic, France, Germany, Italy, Poland, Spain, Sweden and the UK), to show the diversity of situations and outcomes compared to the pan-European perspective. We made specific assessments and projections for each of these Member States, and provided a minimum and maximum range for the EU-27.

Figure 4.6: Overall methodology of the study [Source: Analysys Mason, 2013]



4.3 Step 1: Current spectrum usage

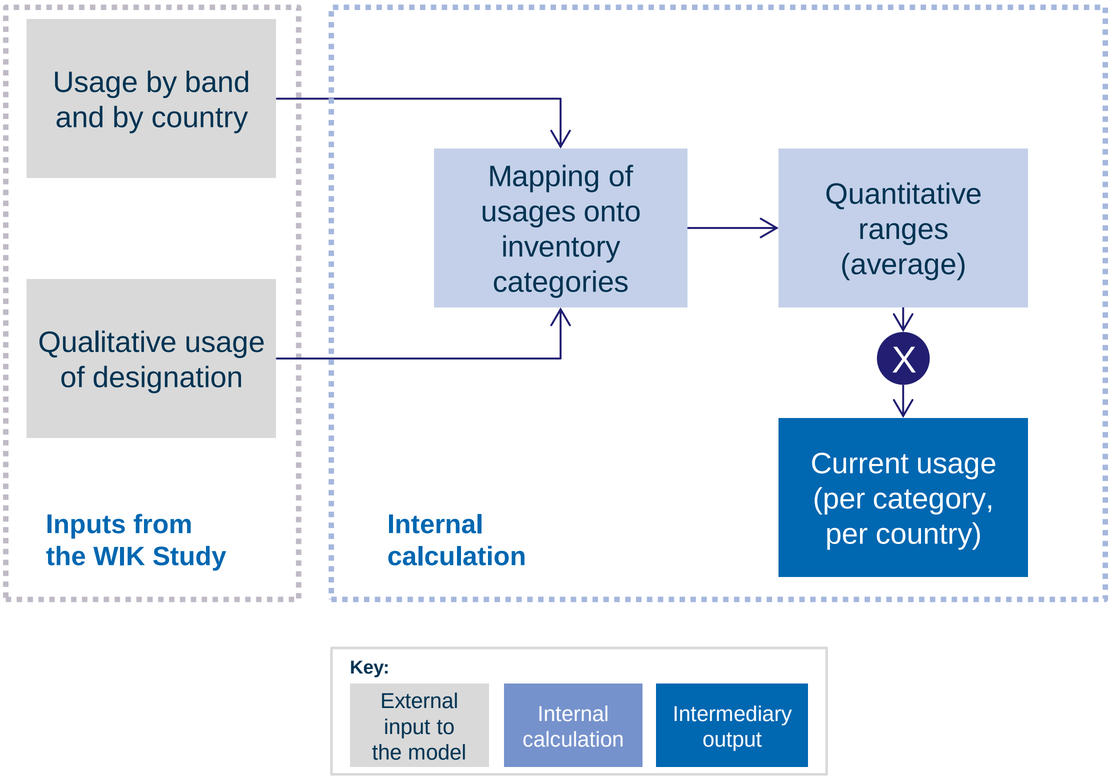
Step one aimed to provide a qualitative picture of the current spectrum usage (since there is not quantitative data), as discussed earlier in this section. The input data was taken from the WIK Study, which provides a qualitative view of relative usage by frequency and category, both nationally and at the EU level. Two datasets were taken from the WIK Study: (a) the usage of individual frequency bands, by country; and (b) the categories of applications operating within these bands, again by country. These two datasets were then used to map the usage of frequencies onto the categories operating in those frequencies, giving current usage level by category and by frequency.

In the WIK Study, a rating scale was applied to each band, namely 0, 1, 2 and 3. We then allocated a quantitative range of usage levels for each point on the scale (i.e. a minimum and a maximum level), as follows:

- 0: from 0% to 35% of the designated spectrum
- 1: from 36% to 55% of the designated spectrum
- 2: from 56% to 75% of the designated spectrum
- 3: from 76% to 100% of the designated spectrum.

The methodology we used to derive current spectrum usage levels is illustrated in Figure 4.7 and described in turn below.

Figure 4.7: Methodology to calculate current usage demand for spectrum [Source: Analysys Mason, 2013]



Given the wide range of current usage levels covered by each of the four ratings (0–3), in order to decrease the level of inaccuracy in the starting point, in calculating future demand in each of the focus countries we based our calculations on the *average* current usage level corresponding to each rating. For example, in the inputs the usage rating 0 covers levels of usage ranging from 0% to 35%, but in our calculations this is normalised to 17.5%.

However, at the EU-27 level, carrying out the analysis based on just the *average* usage across all Member States would not provide a full enough picture: we also needed to consider the implications of usage being at the *low* end or *high* end of the range. For that reason, we also developed a view on the *minimum* and *maximum* current usage across all EU-27.

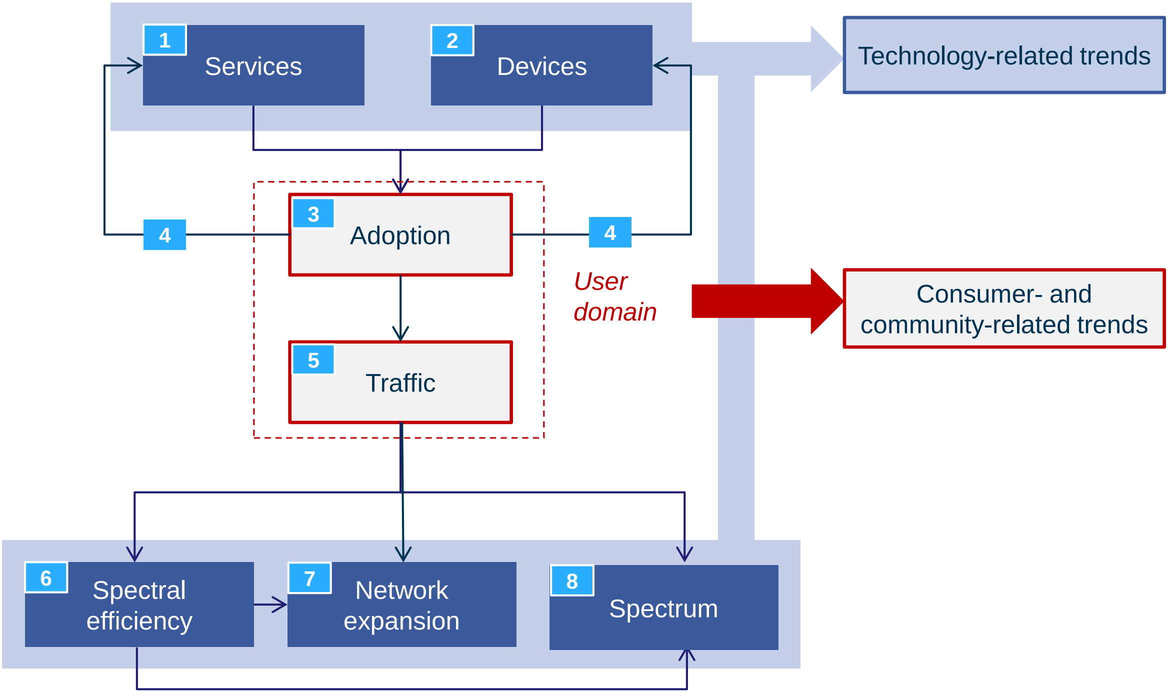
As an output from Step one, we created spectrum 'heatmaps' as a means of representing in relative terms the current average spectrum usage, by study country and by usage category, across the entire frequency range (in steps of 10 MHz). In addition, at the EU-27 level, the heatmaps also showed the minimum, average and maximum current usage. Figure 4.8 below shows an example of such a heatmap, for spectrum used by satellite applications.

Figure 4.8: Example of heatmap showing current average spectrum usage for satellite and by study country, and for the EU27 [Source: Analysys Mason, 2013]

4.4 Steps 2, 3 and 4: Identification and assessment of trends

In these three steps we identified and assessed (a) technology-related trends, and (b) consumer- and community-related trends that affect spectrum usage, for each of the categories of usage. A full summary of these trends and our assessment of their effect on demand for future spectrum usage can be found in Figure 5.1 (page 45) and Figure 6.1 (page 107). We note that the aim of the study is not to develop detailed quantitative forecasts for spectrum usage demand, but to provide some guidelines on how demand is likely to evolve over the period to 2022, and the key factors and drivers that will determine it. Our methodology is shown in Figure 4.9 below.

Figure 4.9: Methodology for identifying and assessing technology, consumer and community trends [Source: Analysys Mason, 2013]



1. Content producers, application developers, over-the-top (OTT) players, and R&D and policy makers produce new and better services and content.
2. Device manufacturers develop more powerful devices which enable the provision of new services, improve the user experience (thus encouraging usage) and in some cases become symbols of social status.
3. End users and communities adopt these new services and devices.
4. Through users' adoption, the penetration of advanced devices encourages service take-up, which in turn improves the adoption of advanced devices.
5. Users' adoption of services and devices increases penetration and usage, and consequently traffic.
6. R&D-driven improvements in spectral efficiency occur for some technologies, which can reduce spectrum usage and allow spectrum to be released for other applications.
7. Operators and service providers expand and improve their networks as far as is financially viable.
8. New spectrum may be made available (on a dedicated or shared basis) for particular applications, generating additional traffic.

For each application, we gathered quantitative evidence of underlying factors and drivers that are likely to influence demand for future spectrum usage within each of the focus countries. As there is a relatively high level of inaccuracy in data on current spectrum usage, and uncertainty as to how these trends will develop, we assessed the impact of trends in broad terms using a five-point scale ranging from -- (more than a 50% reduction in demand) to ++ (more than a 50% increase). This is explained in Figure 4.10 below. Moreover, we assessed the impact over three periods: the short term (2012–2014), medium term (2012–2017) and long term (2012–2022).

Rating	Impact on demand for future spectrum usage
++	More than a 50% increase
+	Up to a 50% increase
=	Limited impact
–	Up to a 50% reduction
– –	More than a 50% reduction

Figure 4.10: Key used in our assessment of the impact of trends on demand for future spectrum usage [Source: Analysys Mason, 2013]

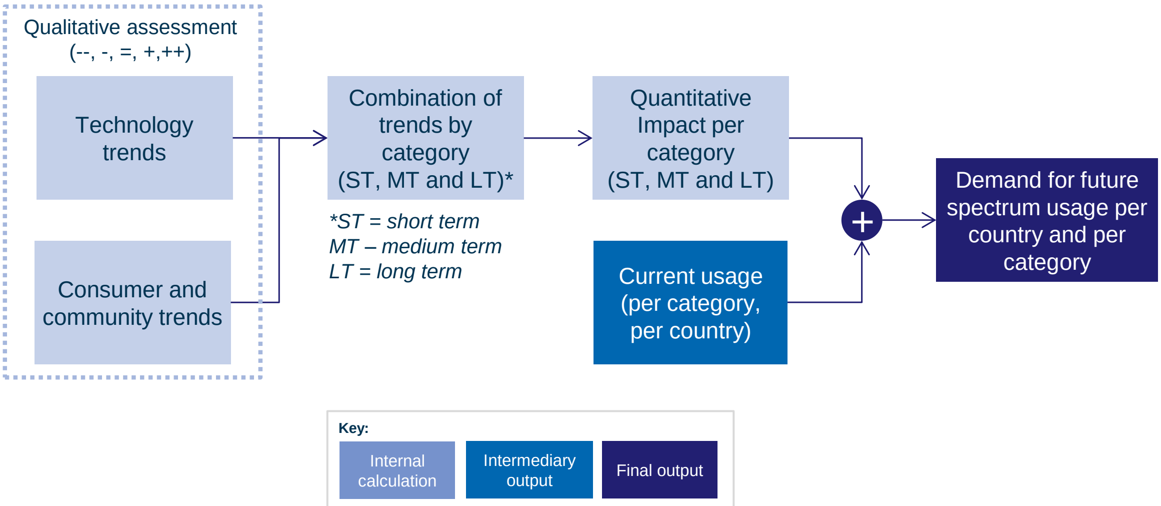
We presented the preliminary results of our assessment to stakeholders during three workshops, and encouraged them to provide feedback and further inputs to ensure that the information gathered was as complete and accurate as possible. Finally, we refined our preliminary results in light of the feedback and input received during and after the workshops, and shared our conclusions with the EC study team.

We therefore believe that, despite the current uncertainties regarding how many of these trends will develop and the differing views of the various stakeholders, the results presented in Sections 5, 6, 7 and 8 of the present document provide a solid foundation for the debate about the direction, scale and timing of demand for future spectrum usage.

4.5 Step 5: Demand for future spectrum usage

Step five was the last step and involved combining all the trends to ascertain their combined qualitative effect on spectrum demand in the short, medium and long term. We then applied these trends to the current usage levels and calculated on a qualitative basis the results for future spectrum usage, which were then presented as heatmaps with the colour coding shown in Figure 4.13. The process by which the current spectrum usage was ascertained and how the trends were combined is illustrated below in Figure 4.11.

Figure 4.11: Methodology for calculating demand for future spectrum usage [Source: Analysys Mason, 2013]



As explained earlier in this report, there is significant inaccuracy in the available data for current spectrum usage; when this is combined with the uncertainty regarding our future growth assumptions, this leads to a wide potential margin of error in the calculated future demand. This is illustrated in Figure 4.12 below, which shows the range of inaccuracy in the usage data as the vertical axis, and the range of uncertainty in the growth assumptions as the horizontal axis. Each of these ranges is broken down into three values in our model, namely a minimum, average and maximum value. Combining them therefore leads to nine outputs, shown as the nine squares in the matrix below. These nine possible outputs have a very wide margin of error, shown by the pink arrow in the figure, as they range from (minimum value for current usage × minimum value for growth) right through to (maximum value for current usage × maximum value for growth).

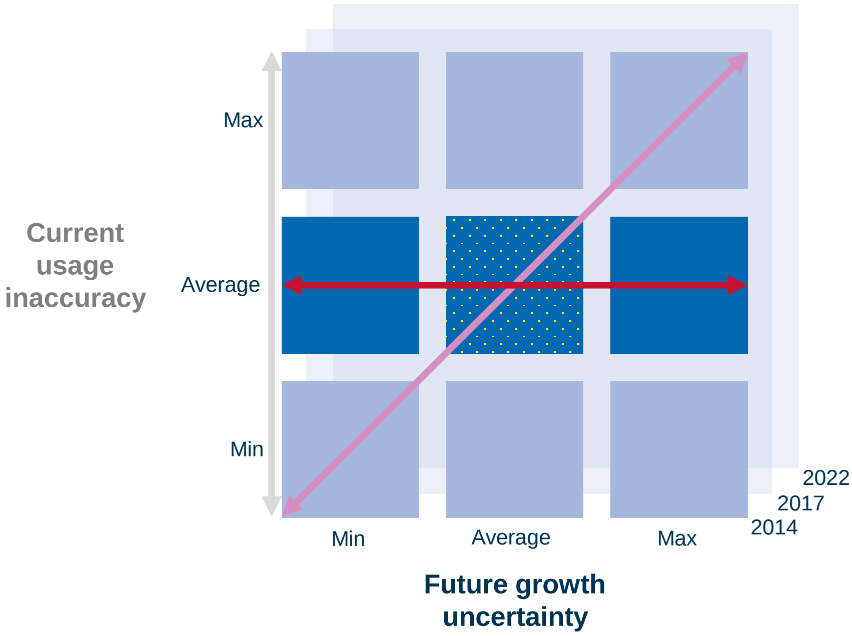


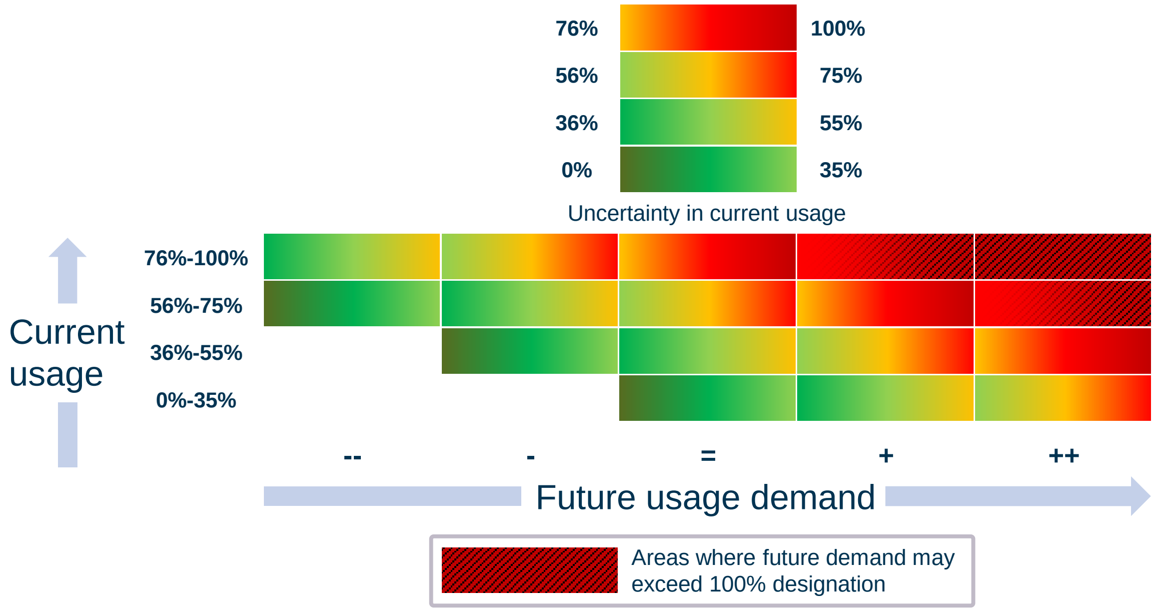
Figure 4.12: Output ranges caused by usage inaccuracy and growth uncertainty overtime [Source: Analysys Mason, 2013]

It is our view that results having such a large margin of error would not form an adequate basis for the current debate. Accordingly, as explained earlier, we have calculated future demand based on the *average* value of each current usage level: e.g. a level of 0 (which covers values ranging from 0% to 35%) is normalised as having a value of 17.5%. This average usage level is then multiplied by the estimated growth factor. This reduces the margin of uncertainty in our results to the range shown by the horizontal red line, i.e. from (average value for current usage × minimum value for growth) through to (average value for current usage × maximum value for growth). These outputs are shown as the three dark blue squares in the matrix above.

There remains some level of uncertainty in our results, which means that they should be interpreted carefully. Nevertheless, we believe our conclusions provide good guidance to understand potential future spectrum usage demand.

We described earlier how we created heatmaps to visually illustrate current spectrum usage. We have used the same method to represent future spectrum usage demand across the EU. Figure 4.13 shows the colour coding that we have used in developing these heatmaps, which may be seen in Section 1.

Figure 4.13: Colour coding for spectrum heatmaps [Source: Analysys Mason, 2013]



The top of the diagram in Figure 4.13 above illustrates how the colour code varies with the level of usage. The lower part of the figure shows how the combination of current usage (vertical axis) and forecast growth (horizontal axis) lead to a range of output values for the demand for future spectrum usage. In Section 7, for each application category we provide a heatmap showing (average current usage × minimum future growth) and another showing (average current usage × maximum future growth). This means that, for example, if at a particular frequency the current usage is level 3 (76–100%) and the forecast growth is rated as + (positive change), then the first heatmap (minimum future growth) will show this frequency as red, while the second (maximum future growth) will show it as red hash. For some applications, the forecast usage demand may exceed the amount of spectrum actually designated for that application: these cases are indicated with diagonal shading. The variance between the minimum and maximum future growth reflect the uncertainty in the growth assumptions.

5 Technology trends influencing the demand for future spectrum usage

This section analyses technology trends by application category, and assesses their relative impact on spectrum usage demand over the next ten years. Some trends (such as cognitive radio) might be relevant to different categories of spectrum use, and so in some cases we have had to carefully consider whether to include a given trend in one category only or across several categories, to capture different perspectives.

This section focuses exclusively on technology trends influencing the demand for future spectrum usage, as well as trends related to the *creation* of new devices and services. The impact is calculated independently for each category of spectrum use; the impact of consumer and community trends on spectrum usage demand is discussed in Section 1.

The table in Figure 5.1 displays the complete list of technology trends, and the overall impact assessment on the spectrum usage demand for each category.

Figure 5.1: Overview of technology trends by category and overall assessments of impact on spectrum usage demand [Source: Analysys Mason, 2013] ST = short term (2012), MT = medium term (2017), LT = long term (2022)

Category	Technology trends	Impact on demand for future spectrum usage		
		ST	*MT*	*LT*
AMCRN	Digital enhancement of communications systems	=/+	=/+	=/+
	Radiolocation services			
	Remotely piloted aircraft systems (RPAS)			
	Wireless avionics intra-communications (WAIC)			
	Direct air-to-ground communication (DA2GC)			
	Digital enhancement of analogue maritime mobile systems			
Broadcast	New digital video formats	+	+	+
	Broadcasting encoding and transmission developments			
	Development of alternative platforms to digital terrestrial television (DTT)			
	Analogue switch-off (ASO) / digital switchover (DSO)			
	Single-frequency network (SFN)			
	Mobile TV / digital video broadcasting – handheld (DVB-H)			
Mobile	Long Term Evolution (LTE) and LTE-Advanced	+	+	+
	More sophisticated devices			
	Techniques for spectrum sharing and use of white spaces			
	Wi-Fi offload			
	Femtocells			
	In-building wireless			
	WiMAX developments			

Category	Technology trends	Impact on demand for future spectrum usage		
		ST	*MT*	*LT*
Defence	Information exchange Positioning and navigation Detection and radar improvements Information acquisition	+	+	+
Fixed	Use of wider channels / higher frequencies Improved modulation techniques Use of XPIC Non-line-of-sight (NLoS) / quasi-line-of-sight (QLoS) backhaul Zero-footprint units Other technology advances Fibre substitution	–	–	–
ITS	New applications Vehicle-to-vehicle (V2V) communications Rail applications	=/+	=/+	=/+
MET	Satellite services Radar improvements	=	=	=
PMR	Digital replacements Smart grids and smart metering	=/+	=/+	=/+
PMSE	Digital microphones Higher-frequency wireless cameras Adoption of 3D/HD cameras Mobile broadcast systems	=/+	=/+	=/+
PPDR	PPDR high-speed data network Use of commercial networks TETRA 2 (TEDS)	=/+	=/+	=/+
Science	More powerful back-end processing Very long baseline interferometry	=	=	=
Satellite	Multi-input element low noise block (M-LNB) L-band mobile satellite service (MSS) Ku-band fixed satellite service (FSS) Galileo navigation system Satellite L-band digital audio broadcasting (DAB) High-speed satellite broadband Mobile satellite broadcasting	=	=	=
SRDs	Technology developments Harmonisation of modulation techniques Medical applications Radio-frequency identification (RFID) devices Geo-location databases	=	=	=
WLAN	New Wi-Fi standards Wi-Fi roaming (offloading) Universal hotspots	+	+	+

Key:
++ More than a 50% increase
\+ Up to a 50% increase
= Limited impact
– Up to a 50% reduction
– – More than a 50% reduction

5.1 Aeronautical, maritime and civil radiolocation and navigation systems (AMCRN)

The aeronautical services category consists of a number of platforms used by civil aviation, such as communications systems. For safety of life reasons, these systems work on internationally designated and harmonised bands; as such, for any technology to have an impact on spectrum efficiency it must be implemented on a continental, if not global, scale. Additionally, according to the General Aviation Manufacturers Association,[13] there were over 320 000 general aircraft worldwide in 2011; clearly for any new technology trend to be widely adopted, the technology would have to be implemented into many of these aircraft, and so trends in this category tend to be gradual; the same is generally true for maritime applications.

Overall, as shown in Figure 5.2, our impact assessment on future spectrum usage demand for AMCRN will mainly depend on:

- new radar technologies, which are likely to increase efficiency and lead to a reduction in spectrum needs, provided these benefits are not outweighed by greater performance of developed/required services
- demand for remotely piloted aircraft systems
- the actual demand for, and commercial success of, direct-air-to-ground communications (DA2GC).[14]

Figure 5.2: Summary of AMCRN technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Digital enhancement of communications systems	=	=	=
Radiolocation services	–/=	–/=	–/=
Remotely piloted aircraft systems	+	+	+
Wireless avionics intra-communications	=	=	=
DA2GC	+	+	+
Digital enhancement of analogue maritime mobile systems	=	=	=
OVERALL ASSESSMENT	**=/+**	**=/+**	**=/+**

13 Source: *General Aviation Statistical Databook & Industry Outlook*, General Aviation Manufacturers Association (2011).

14 These are strictly speaking commercial telecoms services offered to passengers and are not related to safety, and so will not use the aeronautical safety spectrum.

5.1.1 Digital enhancement of analogue communications systems

Figure 5.3: Assessment of the impact of digital enhancement of analogue communications systems on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Short term	Medium term	Long term
Digital enhancement of analogue communications systems	=	=	=

Aeronautical communications systems are currently analogue, and these could potentially evolve to be supported by more spectrally efficient digital systems. It is important to note that analogue communications are unlike to be completely replaced by digital systems for aeronautical uses, as there should always be the option to communicate with a pilot via an analogue voice channel in case of an emergency. Intuitively, this could result in an increase in spectrum usage demand, as there would now be two systems running alongside each other. However, in reality, the digital enhancement of analogue systems is unlikely to have an impact on the spectrum bands within the scope of this study, because:

- this trend is unlikely to develop in the next ten years (the timeframe of the present study), and is more likely to have an impact beyond 2022
- the aeronautical mobile band is currently set at ~118–137 MHz, and so is out of the scope of the present study.

It is, however, important to note the need for global harmonisation in civil aviation navigation and communication technology.

5.1.2 Radiolocation services

Technology trend	Short term	Medium term	Long term
Advances in pulsed radars	=	=	=
Multi-static radars	–/=	–/=	–/=
Continuous wave radars	–/=	–/=	–/=
Automatic Dependent Surveillance – Broadcast (ADS-B) radars	=	=	=
Mode S Elementary (ELS) and Mode S Enhanced (EHS) systems	=	=	=
Wide-area multilateration (WAM) radar	=	=	=

Figure 5.4: Assessment of the impact of radiolocation services on spectrum usage demand [Source: Analysys Mason, 2013]

For the most part, this group of services concerns the use of radar systems for both civil aviation and maritime applications. They make up the largest use of spectrum by the public sector and constitute a large proportion of spectrum designations within the L-band and S-band, with typical usage in the ranges of 960–1350 MHz and 2700–3400 MHz.

The technologies identified focus on reducing out-of-band emissions, and as such allow for more spectrally efficient operations, by reducing the separation between operating frequencies within operating bands. Six key technology trends have been identified:

- advances in pulsed radars
- multi-static radars
- continuous wave radars
- ADS-B radars
- ELS and EHS systems
- WAM radars.

These trends are analysed in turn in the following sub-sections.

Advances in pulsed radars

Pulsed radars work by emitting a short, discrete wave signal. Any reflection of this signal caused by the target object is then received and analysed. The time lapse and the variation in the radar frequency of the reflection allow the radar detector to sense not only the position of objects but also their velocity.

Many suitable waveforms have been identified for this kind of radar. These must strike a balance between spectral efficiency and performance, more specifically the ability to cope with fast-moving objects. The timescales within which this technology will be available mean that it is the one that is most likely to provide significant gains in efficiency of radar spectrum use in the period considered by this study.

Advances in pulsed radar technology that limit out-of-band emissions could lead to more-efficient spectrum use; however, these gains are likely to be used to increase the robustness and safety of the primary radar network, rather than to decrease spectrum usage demand.

Multi-static radars

Multi-static radar systems use continuous wave radar at several sites to enable the location and velocity of objects to be identified. They do this by ensuring communication between sites so that the perceived objects can be triangulated. Figure 5.5 below shows a basic illustration of such a system.

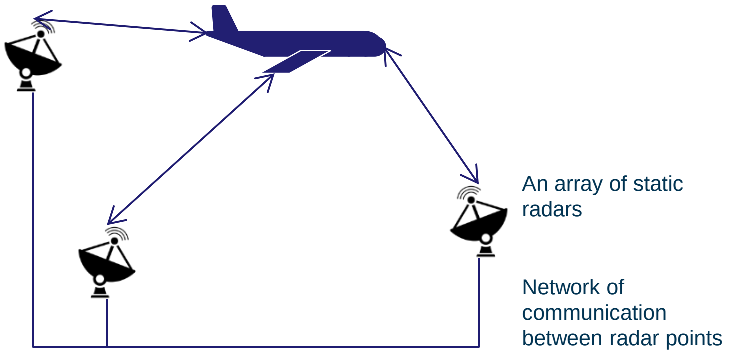


Figure 5.5: Basic illustration of a multi-static radar [Source: Analysys Mason, 2013]

One of the main benefits of this technology is its potential to free up a portion of the 2700–2900 MHz band; its increased spectral efficiency means that the functionality of existing systems could possibly be achieved by just using the top portion of this band. Another benefit could come from energy cost savings, as primary radar systems would no longer need to rotate.

However, the technology is at an early stage of development, and is still very much in its test phase. In reality, it is generally unknown how much more efficient this system could be, and how large the guard bands would need to be between multi-static radar and adjacent applications. Therefore, it is difficult to estimate the impact that this technology will have on spectrum usage demand, and there is a good chance that no benefits will be realised within the next ten years.

Continuous wave radars

Continuous wave radar systems, as its name suggests, uses a single uninterrupted signal rather than a pulsed signal. Although continuous wave radars have the capability to reduce bandwidth requirements due to their enhanced signal-to-noise ratio (SNR), they are currently limited by a number of factors:

- Continuous wave radars suffer from self-interference, which decreases performance levels in comparison to other systems.
- They are unable to give appropriate information on range when used as a single system. When used as a multi-static system with appropriate geometry, they can detect range, but this technology is in its early stages of development and so outside the timeframe being considered for this study.

In summary, if continuous wave radars are able to overcome these limiting factors, they may be able to offer reductions in spectrum needs based on increased spectrum efficiencies, but it is doubtful whether or not this will happen in the next ten years.

ADS-B radars

ADS-B is a radiolocation technology which could become a main system for the surveillance and location of aircraft, as well as air traffic control, in the next decade. Unlike primary radars, which are currently the main system employed, ADS-B consists of a global navigation satellite systems (GNSS) receiver (i.e. Galileo or GPS) in each aircraft, which then broadcasts its position back to the supervisory authority.

ADS-B radars have been in existence for many years, and are operational in several parts of the world, as in the USA, Australia and Canada. In Europe, EUROCONTROL'S CASCADE programme[15] is also focusing on the implementation of ADS-B.

15 The EUROCONTROL CASCADE Programme co-ordinates the deployment of initial ADS-B applications and WAM in Europe.

The 1030 MHz and 1090 MHz frequency bands have also been in use around the world for this purpose for many years, with harmonisation clearly being a key requirement for its widespread adoption. It seems highly unlikely, however, that primary radar systems will be switched off or significantly scaled down as a result of the introduction of ADS-B in Europe in the near future. For example, from a safety perspective, ADS-B requires a working unit on each aircraft, whereas primary radars do not require aircraft to actively respond to the broadcast signal; unlike primary radars, therefore an on-board equipment failure would cause issues for ADS-B.

ELS and EHS systems

ELS systems are an evolution of secondary radar technology, whereby a ground system interrogates an aircraft, which then actively sends a response. Unlike secondary radars, which interrogate all aircraft within range of the ground station, EHS systems are able to actively select which aircraft to interrogate, resulting in better quality and integrity of data received, which could result in improvements in safety, capacity and efficiency in European airspace.[16]

ELS systems offer basic functionality, reporting information such as the aircraft identity and flight status; this will be used for the majority of aircraft within European airspace. EHS systems, on the other hand, offer more advanced reporting, such as roll angle and ground speed; around 60% of commercial aircraft are already equipped with this technology.

As both ELS and EHS systems are based on well-established technologies, it seems reasonable that implementation will continue over the next few years, although because the systems are essentially an evolution of secondary radars, it seems unlikely that they will have a significant impact on spectrum usage demand.

WAM radars

WAM is another evolution of radar technology where a number of ground receivers pick up signals transmitted from an aircraft, and use mathematical techniques (such as time differences of arrival) in order to calculate the location and velocity of the aircraft.[17] WAM works at 1090 MHz, as these transmitters already exist in most aircraft, and the system has been shown to give highly accurate aircraft surveillance information. Therefore, it is possible that WAM will become widespread over the next ten years. Of course, if WAM is able to re-use existing aviation spectrum, it is unlikely to have a major impact on spectrum usage demand.

[16] See http://www.eurocontrol.int/articles/mode-s-operational-overview

[17] See http://www.eurocontrol.int/sites/default/files/content/documents/nm/surveillance/surveilllance-report-wide-area-multilateration-200508.pdf

5.1.3 Remotely piloted aircraft systems

Technology trend	Short term	Medium term	Long term
Remotely piloted aircraft systems (RPAS)	+	+	+

Figure 5.6: Assessment of the impact of RPAS on spectrum usage demand [Source: Analysys Mason, 2013]

Although there is no significant civil market for unmanned aircraft at present, this market is expected to grow during the next 10 to 20 years. According to the ITU,[18] the majority of RPAS over the next decade will be smaller aircraft, as these are likely to be easier to integrate into airspace alongside existing manned aircraft; the development of larger systems is expected to occur around 2022 or later.

There are two aspects of RPAS that require spectrum:

- If unmanned aircraft are going to operate in non-segregated airspace where passenger aircraft operate, they must be integrated safely, with dedicated systems that use aeronautical ‘safety’ spectrum (agenda item 1.5 for the World Radiocommunication Conference 2015 [WRC-2015] deals with this). It is estimated that integrating RPAS into civilian airspace would require an additional bandwidth of ~34 MHz for terrestrial links, and ~56 MHz for satellite links; the 5030–5091 MHz band was deemed to be most suitable for RPAS safety applications at WRC-12.
- Many RPAS applications will require a significant amount of bandwidth for the payload, for example for video links from the air to the ground. It is therefore possible that RPAS will increase demand for L-band MSS spectrum and C-band feeder links. Clearly, this is not specifically an aeronautical safety band, but it will have an impact on the civilian satellite sector (see Section 5.12), and possibly the demand for fixed links (see Section 5.5).

Overall, it seems highly likely that the introduction of RPAS will lead to increased spectrum usage demand, although this will depend on the degree to which the systems are adopted, and the amount of bandwidth that the payloads require.

5.1.4 Wireless avionics intra-communications

Technology trend	Short term	Medium term	Long term
Wireless avionics intra-communications (WAIC)	=	=	=

Figure 5.7: Assessment of the impact of WAIC on spectrum usage demand [Source: Analysys Mason, 2013]

WAIC systems are intended to provide safety-related communications over short distances between stations installed within a single aircraft, but not communications between two separate aircraft, terrestrial systems or satellites.

The candidate bands are on the agenda for WRC-15, but it is likely that they will be above 6 GHz, in which case this trend would not affect spectrum usage demand within the scope of this study. Moreover, this technology trend would appear to be more relevant for the years beyond 2022.

18 ITU (2009), *Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace*. Available at http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2171-2009-PDF-E.pdf

5.1.5 Direct air-to-ground communication

Technology trend	Short term	Medium term	Long term
Direct air-to-ground communication (DA2GC)	+	+	+

Figure 5.8: Assessment the impact of DA2GC on spectrum usage demand [Source: Analysys Mason, 2013]

Note: Although we have included DA2GC under AMCRN, it is a commercial service which is not related to aircraft safety.

DA2GC supports the provision of broadband services on-board aircraft, thus enabling passengers to use services such as mobile communications and Internet access. It is already in use in North America, having been installed on over 1500 commercial and 5000 business aircraft. In Europe, studies are currently being undertaken to identify suitable spectrum for this technology,[19] with a view to offering these services in the near future.

Figure 5.9 below shows an illustration of how a DA2GC system operates. Dedicated base stations communicate with the aircraft via LTE-based links. On the ground, a more conventional cellular network enabled with broadband backhaul acts as a data transport network.

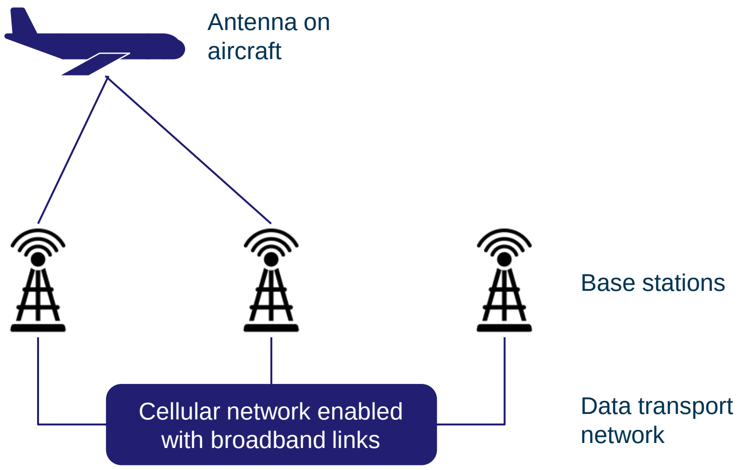


Figure 5.9: Basic illustration of a DA2GC system [Source: Analysys Mason, 2013]

DA2GC will require dedicated spectrum, with overall demand likely to be either 2×10 MHz frequency division multiplexing (FDD) or 20 MHz time division multiplexing (TDD). For the European application, several bands had initially been identified as being potentially viable for this technology. The initial range of bands considered by CEPT ECC FM48[20] in its ongoing report on DA2GC has now been narrowed down to two main bands:

- 1900–1920 MHz and 2010–1025 MHz (the so-called unpaired terrestrial 2 GHz band), and
- 5855–5875 MHz.

[19] See *Proposal for an additional candidate band for DA2GC*, Deutsche Telekom, 2011.

[20] See http://www.cept.org/ecc/groups/ecc/wg-fm/fm-48.

It is important that the bands chosen for DA2GC meet the necessary criteria of harmonisation, existing licences and uses, as well as providing sufficient bandwidth to support the anticipated demand.

A consortium formed by Deutsche Telekom, Airbus and Alcatel–Lucent has carried out trials on several flights using 2×10 MHz of spectrum on a trial frequency in the 2.6 GHz band, achieving peak data rates of approximately 30Mbit/s.

Although DA2GC uses the latest-generation methods, this technology will result in a significant increase in spectrum usage (of around 20MHz), due to its requirement for a dedicated and harmonised designation. In addition, it will also drive up demand for backhaul links (including microwave) on the ground to connect base stations.

5.1.6 Digital enhancement of analogue maritime mobile systems

Technology trend	Short term	Medium term	Long term
Digital enhancement of analogue maritime mobile systems	=	=	=

Figure 5.10: Assessment of the impact of digital enhancements to analogue maritime mobile systems on spectrum usage demand [Source: Analysys Mason, 2013]

The only technological advance that may give rise to increased spectrum efficiency in the maritime mobile category is the introduction of digital equipment (in a similar way to that discussed in Section 5.1.1 in relation to aeronautical services). However, as regards aeronautical applications, the international nature of the applications means they are unlikely to be implemented within the timescales considered for this study.

5.2 Terrestrial broadcasting (Broadcasting)

Television (TV) services can be provided over a plethora of platforms. Traditionally, TV has been delivered in Europe via terrestrial, satellite and cable networks, where available. Terrestrial broadcasting remains a widely used TV platform among a large proportion of consumers in the EU-27. In the last ten years there has been a progressive digitalisation of TV networks (cable, satellite and, more recently, terrestrial). In addition, a combination of the development of IPTV (a managed IP-based TV service running either over a wired or wireless broadband access connection), the increasing take-up of video services (streaming, linear and video-on-demand (VoD)) provided over the Internet, and the proliferation of devices on which video services can be enjoyed (standard TVs, connected TVs, tablets, laptops, notebooks and smartphones) are changing the way viewers watch TV. However, the continued existence of the DTT platform is generally considered as essential, and licence obligations will ensure its sustainability over time (particularly over the next ten years, the focus of this study).

While some improvements (such as the adoption of more effective compression algorithms) have led to greater spectral efficiency, increasing demand for higher-quality and therefore more bandwidth-hungry services could increase spectrum usage, if delivered over terrestrial networks.

Overall, as shown in Figure 5.11, our impact assessment on spectrum usage demand for broadcast mainly depends on:

- the rise in use of new TV quality standards by existing channels (HDTV, UHDTV and 3DTV) and the extent to which their use is offset by improvements in compression techniques (MPEG4 and HEVC)
- the number of TV channels that each market will be able to sustain
- the potentially limited gains from adopting SFNs and the issues of international co-ordination
- the digitalisation of terrestrial TV (analogue switch-off/digital switchover) in Central and Eastern Europe
- the decline of DVB-H in favour of mobile broadband as a means of providing video services on the move.

Figure 5.11: Summary of broadcasting technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
New digital video formats	++	++	++
Broadcasting encoding and transmission developments	=/+	=	– –
Alternative broadcasting platforms	–/=	–	–
Analogue switch-off / digital switchover	–/+	–	–
Single-frequency network (SFN)	–/=	–	–
Mobile TV / DVB-H	–	–	–
OVERALL ASSESSMENT	**+**	**+**	**+**

5.2.1 New digital video formats

Technology trend	Short term	Medium term	Long term
HDTV	++	++	++
3DTV	++	++	++
UHDTV	=/++	=/++	=/++

Figure 5.12: Assessment of the impact of new digital video formats on spectrum usage demand [Source: Analysys Mason, 2013]

HDTV

An increasing number of TV channels are becoming available in high definition (HD) as opposed to standard definition (SD). This is due to a combination of HD-capable TV sets becoming mainstream in Europe, and the rapid development of delivery platforms (such as satellite broadcasting) that can provide the capacity for HD content.

One of the most widespread HD modes is 1080p, which denotes a resolution of 1920×1080 (1080 lines), compared with the original SD European PAL mode, consisting of 625 lines. HDTV channels require significant capacity increase of about 150% (for example, an HDTV channel requires an 8–10Mbit/s data stream, versus 3–4Mbit/s for SDTV using MPEG-2 over DVB-T). However, the increasing use of HDTV is likely to go in tandem with DVB-T2 and MPEG4 encoding, thus reducing the need for additional spectrum (see Section 5.2.2). The amount of terrestrially distributed HD content could increase over the next ten years, particularly if increases in efficiency of broadcasting take place. Some countries, such as the UK, are already broadcasting a number of DTT channels in HD.

3DTV

3D content is achieved through stereoscopic imaging, whereby each half of the TV screen displays a different HD image. The viewer interprets the resulting image by wearing 3D glasses which have either a different polarisation in each lens, or active shutters which operate in time with the TV's refresh rate. In its current form, therefore, there are two critical barriers to mainstream adoption of 3DTV:

- The fact that two simultaneous HD streams are needed to generate a 3D image means that 3DTV uses around 250% more bandwidth than SDTV (for example, a 3DTV channel typically requires around 14Mbit/s)[21] (see Figure 5.13 below). 3D broadcasting is therefore unlikely to be distributed widely over the terrestrial platform.

- The current requirement for 3D viewers to wear glasses is likely to reduce the appeal of the technology to mainstream TV viewers. As a result, the majority of 3D content is likely to be adopted by fewer TV channels (e.g. with a focus on sports content and custom-made 3D films/ animations), and it is unclear whether DTT channels will adopt 3DTV in the next ten years.

Some countries such as the UK are leading the way with 3DTV over pay TV, using alternative platforms such as satellite and cable, but the technology has not yet taken off over terrestrial platforms.

UHDTV

Ultra-high-definition television (UHDTV) could bring a further advance to picture quality. There are two standards for UHDTV:

- 4K/UHD-1 (2160p) channels, which require 24Mbit/s, and a capacity increase of about 500% compared to an SDTV channel
- 8K/UHD-2 (4320p) channels, which would require up to 60Mbit/s (assuming the new HEVC system were to be used; see Section 5.2.2).

Of these two standards, 4K UHDTV is likely to be available in the near future, with some manufacturers already taking orders for 4K television sets. However, at present there is no content available, nor any compatible distribution platform.

[21] 3DTV is not currently widely available over DTT, so this figure refers to alternative distribution platforms such as DTH or cable, which may use either MPEG-2 or MPEG-4 (depending on the CPE that is provided to the user).

Some Japanese manufacturers have demonstrated the 8K standard on extremely large displays, but this technology is still in its early stages with only a handful of such displays in existence, and 8K filming equipment being even more scarce.

It is therefore unclear whether DTT channels in Europe will adopt UHDTV over the next ten years; although the target implementation period is expected to be 2018–2020, it is highly likely to be the alternative broadcasting platforms which offer the technology at first, as a premium service. This is due to the large amounts of bandwidth required, the diminishing perceived improvements in picture quality as video standards continue to advance, and the impracticality of ultra-large displays.

However, various trials are being carried out around the world. For example, 4K broadcasting is being tested in Europe via satellite delivery at 50Mbit/s, using MPEG-4 encoding. Trials of 8K DTT broadcasting are expected in Japan and Korea in 2016 and 2018, respectively. A further development is autostereoscopic 3D, where the viewer is able to watch 3D content on a 4K display without the need to wear special glasses.[22]

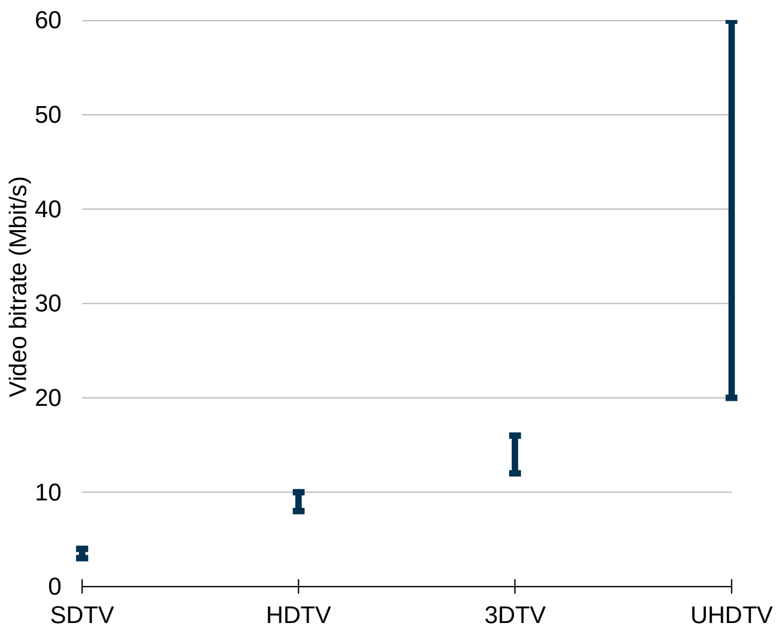


Figure 5.13: Range of bitrates required for different standards of video distribution [Source: Analysys Mason, 2013]

While an increasing amount of HDTV content is likely to be broadcast over DTT, it is difficult to say whether or not 3DTV and UHDTV will follow suit. The ability to broadcast these channels over DTT is likely to be highly dependent on user trends, policy decisions, and the success of new broadcasting compression and encoding systems (see Section 5.2.2).

22 See http://tech.ebu.ch/docs/events/webinar049_BeyondHD-update/hoffmann_beyondHD_update.pdf

5.2.2 Broadcasting encoding and transmission developments

Technology trend	Short term	Medium term	Long term
DVB-T2	=/+	=	– –
MPEG-4 and high-efficiency video coding (HEVC)	=/+	=	– –

Figure 5.14: Assessment of the impact of broadcasting encoding and transmission developments on spectrum usage demand [Source: Analysys Mason, 2013]

A DTT MUX is a designation of bandwidth for the transmission of terrestrial channels. A MUX can deliver any picture quality, including HDTV, providing that the services fit into the available channel capacity and can be received by the end user at a satisfactory quality. To date, it is mainly the DVB-T standard that has been used in Europe, which enables bitrates of between 8Mbit/s and 27Mbit/s per MUX, depending on the modulation scheme used.

There are two main advances in encoding for digital terrestrial broadcasting that could increase spectral efficiency over the next ten years: MPEG-4 video encoding (which is likely to be deployed in parallel with DVB-T2 broadcasting) and HEVC.

DVB-T2

DVB-T2 is the next-generation standard of DTT, which offers an increase in the capacity of a DTT MUX of around 30% when compared to DVB-T. This means that a DVB-T2 MUX could enable bitrates of up to 35Mbit/s, compared to 27Mbit/s for DVB-T. It includes longer guard intervals, to prevent coverage in neighbouring regions from overlapping, and it supports MPEG-4 compression (see below), which will allow MUXs to deliver more TV channels.

DVB-T2 tends to require significant upgrade costs, as the entire MUX transmission equipment must be upgraded to the new standard. As with MPEG-4, there is also likely to be a resulting cost to the consumer, because not all CPE is currently able to receiving DVB-T2 signals.

Figure 5.15 below shows estimates of the number of channels per MUX for a number of different compression schemes.

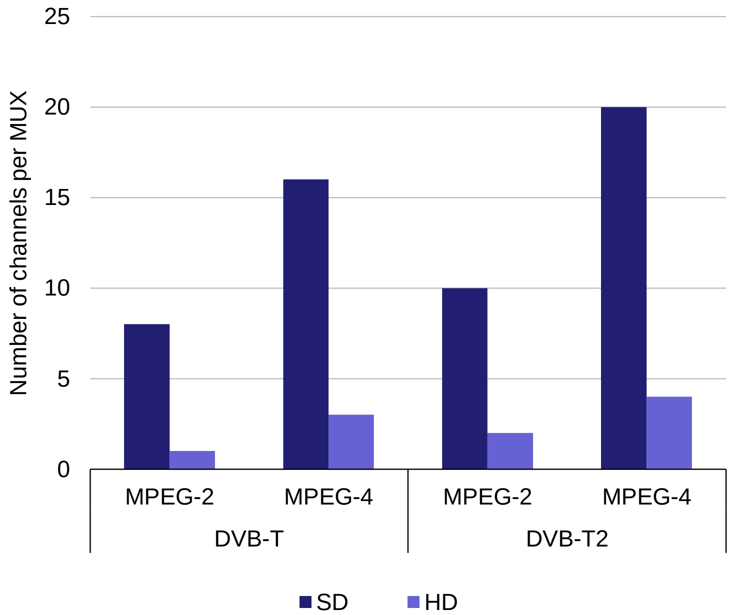


Figure 5.15: Number of channels per MUX for different compression schemes [Source: Analysys Mason, 2013]

MPEG-4 and HVEC

There are currently two main compression technologies that are used for DTT: MPEG-2 and MPEG-4. MPEG-2 is the most widespread, and can carry an SDTV programming channel at 3.2Mbit/s.[23] The version of MPEG-4 that is used for DTT transmission is H.264/AVC, which allows programming to be broadcast at around half the bitrate needed for MPEG-2.

► *MPEG-4*

While upgrading a MUX to deliver MPEG-4 incurs a relatively small network cost, consumers may need to update their CPE in order to receive a TV channel that has been compressed using MPEG-4. There are therefore a number of obstacles in the way of many Member States if they wish to migrate to MPEG-4. This is particularly the case for Member States which have recently completed the DSO (such as the UK), where many viewers will have only recently purchased a DTT set-top box that may not be compatible with MPEG-4. Indeed, according to the European Broadcasting Union (EBU), 200 million DTT receivers have been sold in Europe to date. These receivers are, however, typically backwards compatible, meaning that MPEG-4 enabled receivers can also receive MPEG-2, and a single MUX can transmit both MPEG-2 and MPEG-4 encoded programming side by side.

Overall, it is likely that MPEG-4 will be implemented across many Member States in the next five to ten years, in parallel with DVB-T2. While it is possible that the migration may free up some broadcasting spectrum, it is also possible that the free space will be used to increase the number of HD channels.

In addition, it is highly likely that any upgrade will need to be deployed alongside existing DTT technologies for some time, to allow consumers a transition period (which could be a number of years). As such, it is likely that the roll-out of MPEG-4 and DVB-T2 would lead to an overall increase in spectrum usage demand in the short term, leading to an eventual decrease after the switchover, due to the improved efficiency.

► *HEVC*

HEVC, H.265 is a candidate to succeed MPEG-4, and could offer an increase in compression of up to 70% compared to MPEG-2. It is likely that DVB-T2, in conjunction with HEVC, will be required if demand for 3DTV and UHDTV takes off. The standard is expected to be completed in 2013. However, many Member States have not yet adopted MPEG-4, and so it is debatable whether HVEC will become widespread in the next ten years. As with MPEG-4 and DVB-T2 (above), HEVC would need to be deployed alongside existing broadcast standards for some time, thus leading to an increase in spectrum usage demand during the transition years.

It is worth noting that HEVC is the next generation of video encoding standards, and so is likely to be used over many media/video delivery platforms, not just terrestrial broadcast.

[23] Ofcom (2007), *Review of DTT HD Capacity Issues*.

5.2.3 Alternative platforms to DTT

Technology trend	Short term	Medium term	Long term
Alternative platforms	–/=	–/=	–/=
IPTV	–/=	–	–
Connected TV	–/=	–/=	–/=

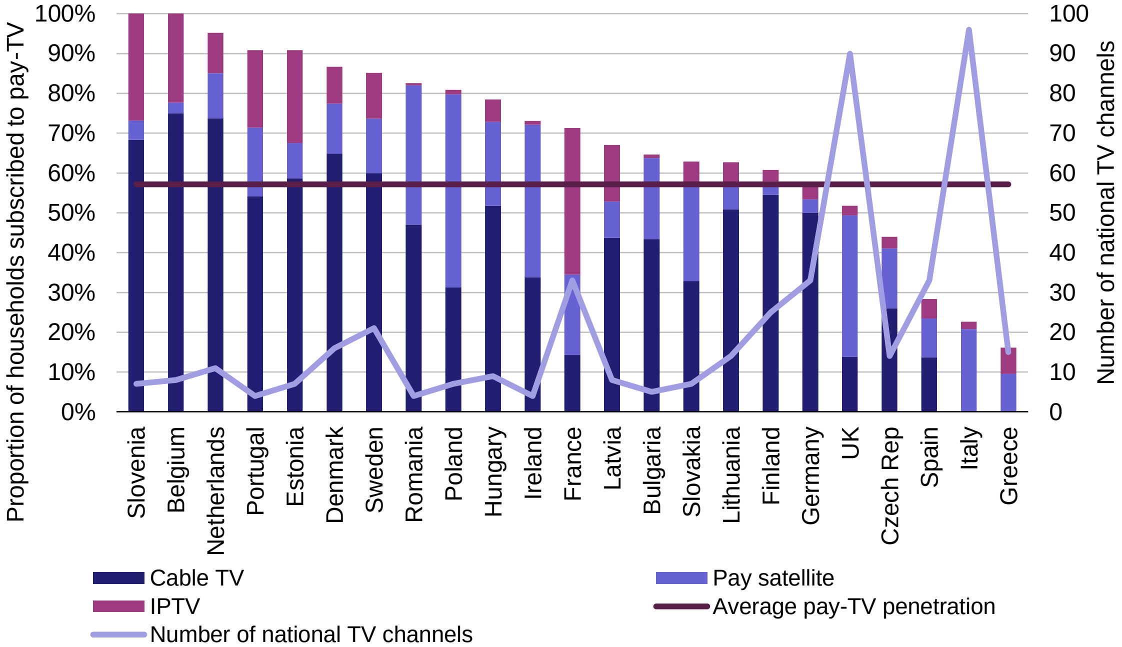
Figure 5.16: Assessment of the impact of the development of alternative platforms to DTT on spectrum usage demand [Source: Analysys Mason, 2013]

Alternative platforms to DTT

A significant proportion of households across the EU-27 receive TV via DTT (e.g. some reports estimate that DTT is received in more than 30% of EU households); however, direct-to-home (DTH), cable and IPTV continue to grow across much of Europe, which could potentially make DTT less attractive in the future. As Figure 5.17 suggests, the popularity of these alternative pay-TV platforms varies greatly across Europe, from ~15% of households in Greece to nearly 100% of households in Slovenia and Belgium. Nevertheless, in most cases DTT is considered essential, and licensing obligations will ensure its sustainability over time.

However, due to the competition among distribution platforms, it is possible that some smaller commercial broadcasters could decide to abandon the DTT platform in the long term if they considered that its fixed transmission costs were excessive compared to the cost of other alternative platforms, and in light of DTT's viewing penetration and viewing share. DTT's impact on spectrum usage demand could be neutral if its sustainability is not challenged, and eventually negative in the long term if some broadcasters (e.g. niche TV commercial channels) conclude that the DTT platform does not provide them with sufficient incremental value.

Figure 5.17: Pay-TV penetration in Europe, 4Q 2011 [Source: Analysys Mason Research, Euromonitor]



IPTV

IPTV provides a means by which viewers can access audiovisual content through Internet-based managed distribution technologies. This can range from online services such as YouTube, to IPTV set-top boxes which deliver content to the consumer's main TV set via an Internet connection. IPTV services are therefore delivered exclusively via an Internet connection; this means that a good, sustained fixed broadband connection is essential for delivering a service that is indistinguishable from broadcast quality. Take-up of broadband is therefore an important driver for IPTV adoption; while some operators such as Portugal Telecom have developed IPTV services in conjunction with new fibre deployments, IPTV can still be provided over standard DSL connections, with this arrangement being particularly popular in France. Figure 5.17 above shows the share of the pay-TV market taken by IPTV in the 23 largest EU Member States.

Overall, IPTV is most likely to be used to distribute premium content, and there is unlikely to be a major impact on DTT spectrum usage over the next ten years as a result of this.

Connected TV

Connected TV is likely to have a small or negligible impact on terrestrial broadcasting spectrum usage in the near future. At present, connected TV typically provides a service that is complementary to traditional TV; it relies on a hybrid system of terrestrial transmissions for live TV (which ensures a good and reliable quality of service) and plain broadband Internet access for provision of on-demand services (e.g. YouTube), catch-up TV services and interactive features. This is a growing trend, with the launch of HbbTV[24] across Europe and YouView[25] in the UK. It could be argued that the continued development of hybrid DTT set-top boxes and integrated DTT TV sets, together with an expansion of services available using the platform could increase the popularity of DTT. Additionally, many of the interactive 'red button' features (such as the ability to watch a sporting event from a choice of camera angles) are available over DTT without the need for an Internet connection.

5.2.4 Analogue switch-off/digital switchover

Technology trend	Short term	Medium term	Long term
Analogue switch-off (ASO) / digital switchover (DSO)	–/+	–	–

Figure 5.18: Assessment of the impact of ASO/DSO on spectrum usage demand [Source: Analysys Mason, 2013]

The switchover to DTT has been completed in most Western European countries, but in Central and Eastern Europe the migration to DTT is likely to continue until 2015. During simulcast (simultaneous broadcasting of analogue and digital signals), the need for spectrum is much higher. This is particularly relevant during the transition period from analogue transmission to DTT, which can last a number of years.

24 Hybrid broadcast broadband TV (HbbTV) is a new initiative across Europe which aims to combine the use of broadcasting and broadband for content delivery over set-top boxes and connected TV sets.

25 YouView is a subscription-free service consisting of a set-top box which combines live TV over DTT with catch-up TV over a broadband connection.

The amount of spectrum used for simulcast during ASO depends on the number of MUXs (typically 5–6 per country, although this does vary significantly across Member States). However, once ASO spectrum is freed up, it can be used to provide additional TV channels for the equivalent previous numbers of TV channels (typically 5–8 extra).

National policy decisions will have a significant impact on the number of MUXs in each Member State, as well as the demand for the number of TV channels; these factors are likely to be the most important in determining the overall demand for broadcasting spectrum. The number of MUXs in the eight focus Member States are as follows:

- Czech Republic: 4
- Germany: 5
- France: 8
- Italy: 16
- Poland: 3
- Spain: 8
- Sweden: 7
- UK: 6

5.2.5 Single-frequency networks

Technology trend	Short term	Mediu m term	Long term
Single-frequency networks (SFN)	–/=	–	–

Figure 5.19: Assessment of the impact of SFNs on spectrum usage demand [Source: Analysys Mason, 2013]

Although the use of SFNs has increased significantly, some Member States operate a multi-frequency network (MFN), whereby different regions of the State use separate frequencies for their MUXs. This allows a greater regional variation in programming, although in practice this may be limited to regional news programmes on some TV programming channels.

The move to an SFN involves using a single frequency throughout the entire State, which in turn could reduce the amount of spectrum that is required for broadcasting. However, such a move could give rise to significant interference issues. For example, with SFN multiple masts transmit at the same frequency, which could cause destructive interference of the broadcast carrier signal for receivers in some locations. This could result in the requirement for lower-powered transmitters and therefore a more-dense transmission network, which is likely to require significant capital investment. Furthermore, this sort of dense low-power network is untried and untested in Europe, and could result in consumers having to reposition their roof antennas (if the location of the nearest transmitter changed), or upgrading to a wideband antenna.

A further challenge is that because broadcast signals spill over across borders, implementation of the existing EU-wide DTT arrangement has taken a significant amount of international co-ordination and negotiation regarding the frequency plan employed in the 470–862 MHz band. A move to SFN would also have to be internationally co-ordinated, and arrangements would have to be renegotiated, taking into account any ‘digital dividend’ spectrum that has already been released in some Member States following the DSO. Finally, we understand from contributions made to the workshop in December 2012 that DTT frequency planning across Europe is already thought to be very efficient, and so a move towards greater national SFNs would be unlikely to provide significant advantages over the existing scheme in terms of spectral efficiency from a pan-European perspective.

5.2.6 Mobile TV/DVB-H

Technology trend	Short term	Medium term	Long term
Mobile TV/DVB-H	–	–	–

Figure 5.20: Assessment of the impact of mobile TV / DVB-H on spectrum usage demand [Source: Analysys Mason, 2013]

Mobile TV is the use of a dedicated broadcast network to provide TV services to portable devices such as mobile phones, smartphones and tablets. The original standard, DVB-H (digital video broadcasting – handheld) has been in existence since 2004, but has seen limited adoption.

Some stakeholders consulted for this study are aware of the increasing demand for mobile data (see Section 6.3) which is in part due to video consumption, and believe that the mobile TV standard could still offer a way of providing a similar service without the need for mobile networks; DVB-T2 Lite and DVB-NGH are two of the standards that are emerging for mobile data. Some stakeholders also believe that existing broadcast networks could potentially be used for a number of other one-to-many data distribution applications, such as the provision of software updates without overloading standard mobile networks; indeed, there is a specification in existence for this sort of distribution model based on mobile networks (eMBMS, see Section 5.3.1). However, currently the vast majority of mobile devices do not support mobile TV standards, which is likely to pose a significant barrier to the adoption of mobile TV.

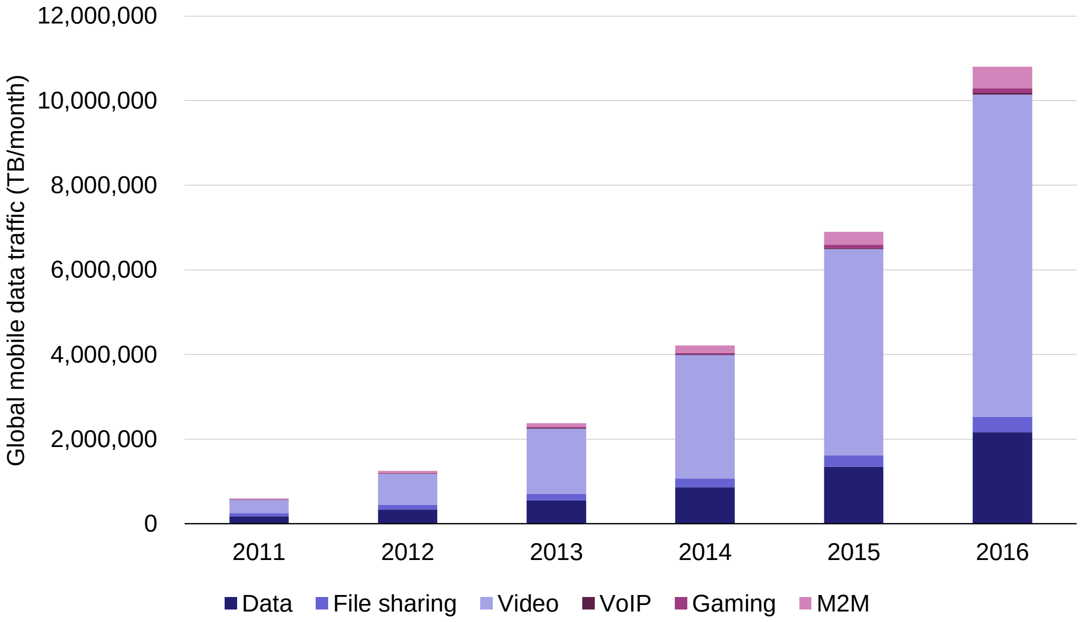
Over the next ten years, it is likely that there will be limited spectrum demand associated with DVB-H; this designation could then be re-assigned for other uses in those Member States (e.g. Italy) where DVB-H licences were granted in the past decade. As a result of this, the majority of mobile TV may be delivered over mobile broadband, thus increasing demand for mobile spectrum (see Section 6.3). In some Member States, such as France, where spectrum was originally designated to DVB-H, it has already been re-designated to DTT, and so much of the potential reduction in spectrum usage demand from DVB-H spectrum being handed back may have already been realised.

5.3 Cellular/BWA (Mobile)

The mobile services category represents spectrum that is designated for the provision of mobile telephony and data, and mobile broadband.

Although forecasts vary, most sources expect a significant increase in mobile traffic over the next five to ten years, driven by both user and technology trends. In the case of mobile, advances in technology are also drivers for changes in usage; for example, as mobile data download speeds increase, the more practical mobile streaming video will become available. This will have an impact on demand for the service, thus increasing the amount of traffic and eventually demand for spectrum, as suggested in Figure 5.21. At the same time, however, advances in technology will increase the efficiency of spectrum usage, and so counteract this effect to some extent.

Figure 5.21: Global mobile data traffic by application type [Source: Cisco VNI, 2012]



In Europe, there are three main mobile technologies that are commercially available:

- **GSM** is a second-generation (2G) technology which was released in 1990 and rolled out during the subsequent decades. It was later upgraded with GPRS (also known as 2.5G), which provided packet-switched data transport, and later EDGE (also known as 2.75G), which allowed improved data rates.
- **UMTS** is a third-generation (3G) technology which complies with IMT-2000 specifications and was launched commercially across Europe in the early 2000s. UMTS was designed to offer greater spectral efficiency than GSM, and allowed higher data rates, although at the time the trend towards mobile broadband had yet to be seen. UMTS was later upgraded with HSPA standards, HSDPA, HSUPA and HSPA+ (known as 3.5G).
- **LTE** is the latest commercially available mobile technology, which is now being deployed in many Member States (see Section 5.3.1). Strictly speaking, LTE is a pre-4G technology, because it is not fully compliant with 4G standards as defined in IMT-Advanced specifications.

HSPA+ and LTE, together with WiMAX[26] (which has had lower take-up in Europe to date), are marketed as '4G', even though it is only their evolutions LTE-Advanced and WiMAX 2 (IEEE 802.16m) which are fully compliant with 4G standards as defined in IMT-Advanced specifications. The ITU has recently defined LTE-Advanced and WiMAX 2 as 'True LTE'.[27,28]

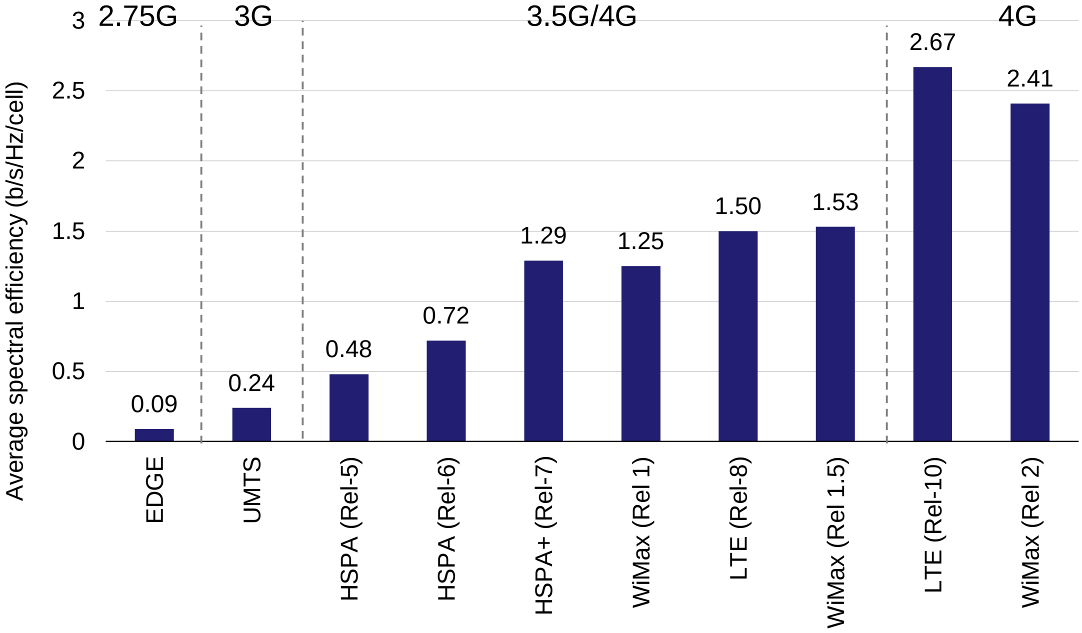
26 See Section 5.3.7 for more details.

27 See http://www.itu.int/newsroom/press_releases/2009/48.html

28 See http://www.itu.int/net/pressoffice/press_releases/2012/02.aspx

Regardless of how this is achieved, the most important improvement that newer technologies bring is measured in terms of spectral efficiency, i.e. the amount of information that can be transmitted per unit of frequency used. As a brief overview of the technologies employed by mobile services, Figure 5.22 below shows the average spectrum efficiencies provided by both 3G and 4G technologies. More details on the component technologies that lead to these efficiencies are discussed in Section 5.3.1.

Figure 5.22: Mobile technology spectrum efficiencies [Source: Qualcomm, Analysys Mason, 2013]



We note that, historically, mobile technology trends have occurred in cycles of around ten years, and so it could be expected that a new generation of mobile technology (‘5G’) might appear in the first half of the 2020s. However, as it is unclear what that technology might be, and it is unlikely to be commercially available before 2022, 5G is not expected to have an impact on spectrum usage demand in the next ten years.

Overall, as shown in Figure 5.23, our final impact assessment on future demand for spectrum for mobile will mainly depend on:

- 3.5G/4G (LTE/LTE-Advanced) technologies
- technological advances in devices which could allow the use of more data-hungry applications on the move
- the integration of Wi-Fi transceivers in most consumer electronics devices (such as TVs, tablets and smartphones)
- spectrum sharing and white spaces
- the deployment of femtocells and in-building wireless.

Figure 5.23: Summary of mobile technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
LTE and LTE-Advanced	=/+	=	– –
More sophisticated devices	++	++	++
Spectrum sharing and white spaces	–	–	–
Wi-Fi offload	–/– –	–/– –	–/– –
Femtocells	–	–	–
In-building wireless (IBW)	–/=	–/=	–/=
WiMAX developments	–/=	–/=	–/=
OVERALL ASSESSMENT	**+**	**+**	**+**

5.3.1 LTE and LTE-Advanced

Technology trend	Short term	Medium term	Long term
Launch of LTE	=/+	=	– –
LTE-Advanced	=/+	=	– –
Evolved multimedia broadcast / multicast service (eMBMS)	–/=	–/=	–/=

Figure 5.24: Assessment of the impact of LTE and LTE-Advanced on spectrum usage demand [Source: Analysys Mason, 2013]

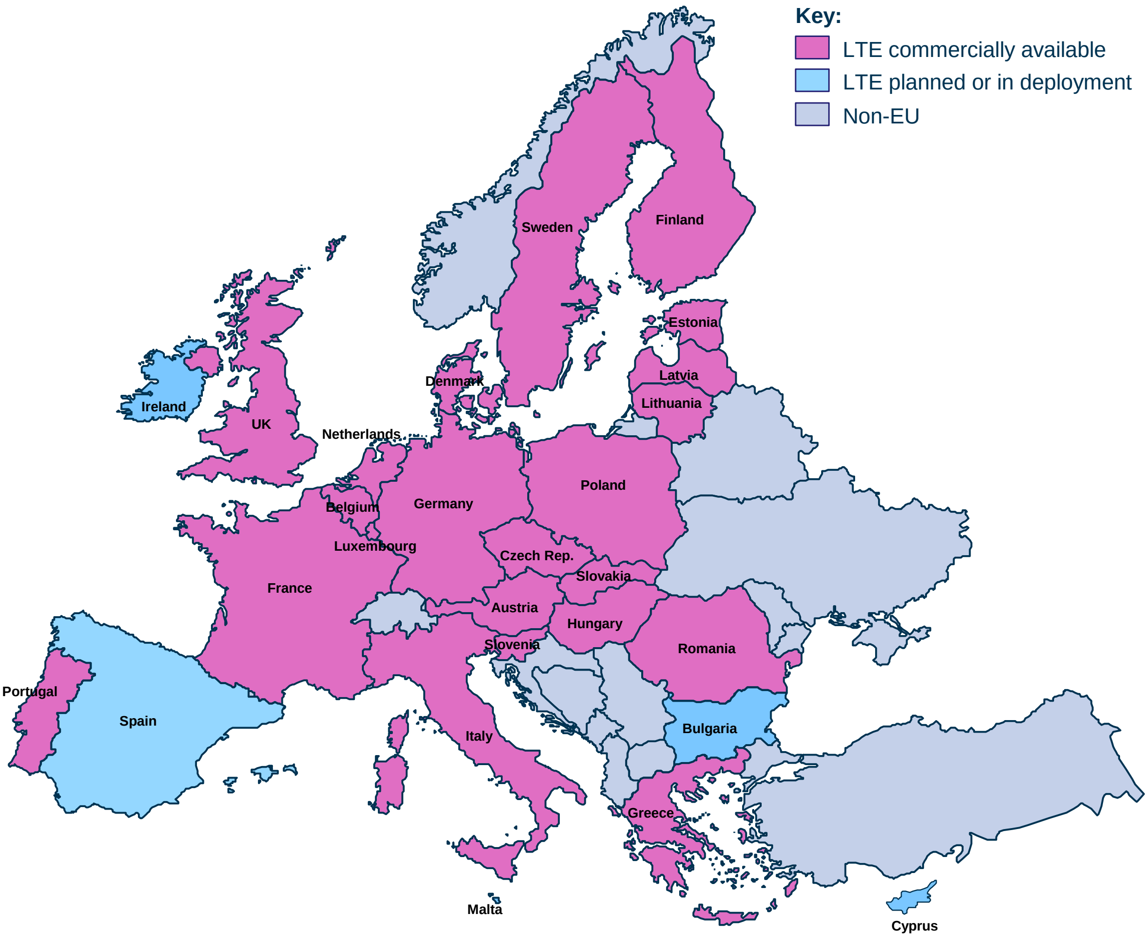
LTE

LTE is widely considered to be the main 4G standard worldwide, and is currently in deployment in many European countries. In terms of standards, LTE strictly refers to the Third Generation Partnership Project (3GPP) Release 8 and Release 9. LTE's extension, LTE-Advanced (Release 10 and Release 11, which is the last one approved by 3GPP) incorporates a number of advances which aim to give further significant gains in spectral efficiency over the next ten years.

LTE had already launched in 22 Member States by January 2013, and is expected to be launched in the other five by the end of 2013, as shown in Figure 5.25. We do not expect LTE-Advanced to be deployed commercially on a wide scale until 2015–2017.[29]

29 It has been recently reported that Russia's Yota has deployed in Moscow, although LTE-Advanced capable devices will not be available until 2013.

Figure 5.25: LTE deployments within the EU as of January 2013[30] [Source: GSA, GSMA, TeleGeography, Analysys Mason, 2013]



These new mobile technologies deliver higher spectral efficiency through a set of technical improvements, such as:

- *Multiple-input multiple-output (MIMO) antenna systems*, which increase throughput with the same amount of spectrum by employing multiple antennas at both the transmitting and receiving end.
- *Enhanced modulation and coding efficiency*, which allows the frequency encoding employed to vary depending on a number of factors (such as the quality of the radio channel), in order to optimise throughput.
- *Co-ordinated multi point*, where different cells share information on a user. By doing this they can either share the data between the cells or use information on the user to ensure reduced interference.

30 LTE has also been deployed in a number of neighbouring non-EU Member States, such as Norway.

These technologies are described in more detail in Annex B. Two technology-related issues associated with LTE will determine its impact on the spectrum usage demand from mobile:

- Although LTE is standardised for all existing bands, the time required to migrate the subscriber base to LTE means that all network generations will be run in parallel for the next decade. For this reason, Member States have generally assigned some dedicated additional frequencies to LTE and liberalised the other bands.[31]

- It is possible that the success of LTE in some bands will depend on the mass availability of chipsets at those frequencies; this will in turn depend on which bands end up being the most widely used for LTE around the world.

LTE-Advanced

LTE-Advanced will improve LTE's spectral efficiency by combining:

- Higher-order MIMO antennas (i.e. more input antennas and more output antennas, rising to 4×4).[32]

- Co-ordinated multipoint (co-ordinated scheduling and joint-processing).

  — *Joint processing*: when user equipment has multiple serving cells, user data can be transmitted (or received) in multiple locations. By enabling sharing of this data between these locations capacity can be increased and interference reduced.

  — *Co-ordinated scheduling*: when user equipment has one serving cell no user data sharing is required. Scheduling information is shared between neighbouring cells with a view to reducing or avoiding interference. This information could relate to power, load, beamforming weights, and so forth. This scheme requires less sharing and processing than joint processing and so does not achieve such high capacity gains.

- Carrier aggregation, where multiple 'component carriers' can be aggregated, instead of simply increasing single carrier bandwidth. This enables aggregation over non-adjacent spectrum designation, and so gives a much higher effective bandwidth.

These improvements allow for a more efficient use of spectrum, both intra-band and inter-band (see Annex B for more detailed explanations of these). However, because many Member States have already assigned new mobile designations to LTE and its evolutions, it is likely that any advances in efficiency (spectrum reduction) will be used to improve throughput/user experience (increased consumer demand).

[31] For example, there has been some 're-farming' of spectrum bands in some cases; for example, mobile operator EE in the UK has re-assigned part of its GSM 1800 MHz band for LTE use.

[32] That is, the use of four antennas on both the device and the base station, thus increasing throughput.

eMBMS

eMBMS is a point-to-multipoint service which forms part of the 3GPP standard and is included in LTE Release 9. The system is designed to distribute linear and video and data services to customers in areas where there is specific demand for the same information. For example, this could be distributing a live video feed at a sports event, or providing a periodic software update. As such, one of the aims of the system is to minimise cell spectrum usage by distributing content that is in high demand as efficiently as possible; this can be over a single cell, region or entire network. Qualcomm demonstrated the system in early 2013 using 10 MHz of mobile spectrum in the USA.[33]

It appears that the technology itself is likely to lead to a reduction in spectrum usage demand due to the increase in efficiency video delivery; however, it is usage patterns that will determine to what extent this reduction will be.

Overall impact

As mentioned earlier, there is an overall trade-off between the increase in throughput and the decrease in spectrum usage that the technologies allow. However, in terms of technology trends alone, with both LTE and LTE-Advanced, in the long term, the increased spectral efficiency would ultimately lead to a reduction in spectrum usage demand. However, as previously mentioned, many Member States are assigning new spectrum for LTE, leading to an increase in spectrum designation and usage in the mobile category, and a short-term increase in spectrum usage demand. An additional complication for LTE-Advanced is that it is unlikely to be launched on a wide scale until the late 2010s or early 2020s, by which time LTE will already be widespread. This means that LTE-Advanced may have only a limited impact on spectrum usage demand during the timeframe of this study, unless new spectrum is designated specifically for it, which appears unlikely at present.

5.3.2 More sophisticated devices

Technology trend	Short term	Medium term	Long term
More sophisticated devices	++	++	++

Figure 5.26: Assessment of the impact of more sophisticated devices on spectrum usage demand [Source: Analysys Mason, 2013]

The last five years have seen the mass-market success of devices such as smartphones and tablets. As a result, manufacturers will continue to design and manufacture more sophisticated devices that encourage higher data consumption, by integrating:

- a larger screen for better video consumption
- a more powerful chipset and operating system for more sophisticated applications
- a multi-band radio chipset for maximum LTE coverage
- higher levels of performance.

33 See: http://www.anandtech.com/show/6635/lte-broadcast-embms-shown-running-on-verizons-band-4-lte-on-qualcomm-hardware

This effect will be compounded by the increase in penetration of such devices and the associated user trends. This is a global trend, notwithstanding significant differences in smartphone and tablet penetration among Member States.

5.3.3 Spectrum sharing and use of white spaces

Technology trend	Short term	Medium term	Long term
Techniques for spectrum sharing and use of white spaces	–	–	–

Figure 5.27: Assessment of the impact of spectrum sharing and use of white spaces on spectrum usage demand [Source: Analysys Mason, 2013]

Spectrum sharing, though not necessarily a technological advance in itself, is linked to the potential advances in cognitive radio and other techniques for spectrum sharing and exploitation of white spaces. The idea of cognitive radio is that the system has the ability to be fully aware of its surroundings (i.e. the spectrum and its current state of use), and from this information it is able to choose the most suitable frequency on which to transmit. In this way, greater spectral efficiency can be achieved. These advances, along with the relevant changes in regulation, constitute a much larger overarching topic which could in future lead to significant increases in spectrum efficiency.

The larger the block of spectrum that is to be shared, the higher the efficiency gain, which allows users of different technologies to be accommodated within the same spectrum space. Standardisation efforts are being focused on areas such as rural broadband.

There are, however, a number of issues that need to be addressed with regard to developments in both software and hardware to support spectrum sharing. Firstly, all relevant devices would need to be equipped with standardised hardware. This is one of the main obstacles to the development of cognitive radio, as it is proving difficult to design hardware that has the capability to operate over many different frequencies. In addition, there would obviously be a need for significant changes in software. Software would be needed both to enable the functionality of cognitive radio and also to facilitate the concept of ‘machine learning’ (a process whereby systems alter and optimise their operation based on previous experience, thus further increasing efficiency).

Additionally, it seems a reasonable assumption that mobile network operators will continue to require exclusive access to spectrum in order to operate reliable nationwide services with the quality of service that consumers have become used to, and so shared access is likely to complement existing mobile services. For this reason, there may be some limitations to the efficiency savings that can be achieved from the shared use of spectrum.

It is difficult to determine the timescales within which any of these advances might occur, given the regulatory issues that would also need to be addressed. Although it is likely that the technology could be available in the next few years, the associated regulatory reforms could take much longer. Therefore, while it seems likely that these advances could lead to significantly increased efficiency in spectrum use, it seems less likely that the impact will be seen in the next five to ten years.

5.3.4 Wi-Fi offload

Technology trend	Short term	Medium term	Long term
Wi-Fi offload	–/– –	–/– –	–/– –

Figure 5.28: Assessment of the impact of Wi-Fi offload on spectrum usage demand [Source: Analysys Mason, 2013]

Wi-Fi has become a ubiquitous technology within many consumer electronic devices (smartphones, tablets, notebooks, laptops and TV sets), with more than half of data traffic from smartphones now being routed via Wi-Fi networks,[34] both private and public. This ultimately leads to a reduction in spectrum usage demand in the mobile category, as discussed here, but an increase in spectrum usage demand as far as Wi-Fi is concerned (see Section 5.14, where Wi-Fi developments are discussed in greater detail).

Wi-Fi is being used in two ways:

- *private Wi-Fi*, whereby consumers connect their Wi-Fi-enabled phones to their Wi-Fi routers when at home or in the office
- *public Wi-Fi*, whereby operators increasingly use public Wi-Fi hotspots as a means of offloading traffic from mobile networks.

This reduction in spectrum usage demand is countered by the general trend for an increase in data use by devices, although this is outside the scope of the impact assessment presented in this report. As far as usage of the current spectrum designation for Wi-Fi is concerned, we also note that the Wi-Fi ecosystem has developed mainly in the 2.4 GHz band, while 5 GHz remains lightly used.

The growing popularity of Wi-Fi has made Wi-Fi an important bridge between cellular data networks and fixed broadband networks, due to the increasing use of mobile devices such as smartphones and tablets which are equipped with both cellular and Wi-Fi chipsets. It is worth noting that this trend could lead to an increase in the traffic carried on fixed broadband networks, which could in turn cause congestion in fixed broadband operators' core networks.

5.3.5 Femtocells

Technology trend	Short term	Medium term	Long term
Femtocells	–	–	–

Figure 5.29: Assessment of the impact of femtocells on spectrum usage demand [Source: Analysys Mason, 2013]

The idea of a femtocell is to create an area of cellular coverage within a comparatively small area, such as a home or small office. Femtocells are consumer-installed 'cells' which offer coverage of 10–30m and use fixed broadband to provide backhaul to the mobile operator's network.

[34] EC Communication COM(2012) 478 (2012).

From a spectrum usage perspective, the benefits of encouraging femtocell use are two-fold:

- enhanced network capacity is an intrinsic benefit and comes from the ability for spectrum to be reused at a higher density across the network
- the use of a smaller cell size leads to increased spectrum efficiency; smaller cell size gives a better SNR, and so better quality of service.

These benefits are, however, subject to various constraints and challenges. Perhaps the most limiting factor, i.e. interference, has already been overcome by developing technologies to allow co-channel operation within a macrocell. One significant barrier at the moment is the fact that the cell is dependent on the user's broadband connection; this must provide sufficient capacity to act as the backhaul for the cell. Because femtocells rely on fixed broadband, their take-up obviously depends on broadband penetration, which varies significantly by Member State. Furthermore, it is noted that in some cases, femtocells that are well isolated from the macro network may be used as a substitute for home Wi-Fi access, and so will not have a role in increasing the capacity of the overall network; as such, these specific isolated femtocells will not lead to a reduction in spectrum usage demand.

5.3.6 In-building wireless

Technology trend	Short term	Medium term	Long term
In-building wireless (IBW)	–/=	–/=	–/=

Figure 5.30: Assessment of the impact of IBW on spectrum usage demand [Source: Analysys Mason, 2013]

This is a technology trend which sits alongside Wi-Fi offloading and femtocells. It would involve property landlords installing multi-technology/multi-operator base stations in their building to host traffic on a neutral basis, but using the same (licensed) spectrum as the macro network. As with femtocells, such installations would use fixed backhaul and could reduce the spectrum usage demand in the mobile category, as they would be designed to offload indoor traffic from the macro network, thus allowing increased frequency re-use across the network. Unlike femtocells, IBW networks could be custom-designed and scaled for each building, thus making the most efficient use of the available spectrum. However, it remains to be seen how popular this trend will be; indeed, mobile operators have expressed concern regarding their loss of control of base stations, which they believe could have an impact on quality of service.

5.3.7 WiMAX developments

Technology trend	Short term	Medium term	Long term
WiMAX developments	–/=	–/=	–/=

Figure 5.31: Assessment of the impact of WiMAX developments on spectrum usage demand [Source: Analysys Mason, 2013]

WiMAX refers to families of the 802.16 standard, and provides wireless broadband access using licensed spectrum. The original standard was published in 2001, but the technology has not seen significant take-up in many Member States. However, the targets set by the *Digital Agenda for Europe* (DAE) are likely to lead to the need for such a wireless service for rural broadband application:

- WiMAX Release 2 (802.16m) adds features such as 4×4 MIMO technology, and is expected to provide data rates that are appropriate for meeting the DAE coverage obligation (30Mbit/s+ to all households by 2020). This technology may be particularly relevant in Member States that have a large rural population, or where the copper access network is more limited; indeed, the suitability of WiMAX as a 'last-mile' technology has contributed to its success in developing parts of the world, such as Africa.
- A migration of WiMAX networks to the TD-LTE standard may also take place, with some newer WiMAX equipment being upgradable to TD-LTE. Because TD-LTE is a TDD technology, this means it can use unpaired spectrum. In the UK, for example, some mobile network operators hold unpaired 2 GHz TDD spectrum at 2 GHz, which is currently unused, and could potentially be used for WiMAX or TD-LTE applications if there was sufficient demand for such a service.

Overall, the impact of WiMAX on spectrum usage demand will largely depend on whether WiMAX or TD-LTE technologies are used to help meet the DAE targets; this will therefore vary across Europe depending on local geographical and demographic factors. WiMAX is normally deployed at 2.3 GHz, 2.5 GHz or 3.5 GHz, and in many Member States this spectrum has already been licensed to operators, so it seems that spectrum usage demand will either remain steady or decrease if the assignments are handed back.

5.4 Defence systems (Defence)

The defence systems category encompasses a very broad range of technologies and spectrum uses, and includes demand for all systems that are used by the defence community. In some cases these systems will use spectrum bands managed by the military, and in some cases commercial or other privately held spectrum bands may be used. In addition, it should be noted that, in most Member States, many military bands are shared with other civilian uses, and advances such as dynamic spectrum access could lead to further sharing in the future, both within the defence sector and cross-sector.

Overall, as shown in Figure 5.32, our impact assessment on future demand for spectrum for defence will depend on:

- the assumption of limited changes in positioning and navigation technologies
- the implementation of new applications such as information acquisition and exchange
- the potential compression/efficiency benefits from new detection radar and transmission technologies (although these are likely to lead to increased performance rather than reduced usage).

Figure 5.32: Summary of defence technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Information exchange	++	++	++
Positioning and navigation	=	=	=
Detection and radar improvements	=	=	=
Information acquisition	+	+	+
OVERALL ASSESSMENT	**+**	**+**	**+**

5.4.1 Information exchange

Technology trend	Short term	Medium term	Long term
Information exchange	++	++	++

Figure 5.33: Assessment of the impact of information exchange on spectrum usage demand [Source: Analysys Mason, 2013]

Information exchange represents the general trend towards enhanced connectivity among all military staff, devices and defence assets, known as a net-centric approach, and is similar to the Internet of Things. This trend is likely to mean that tactical communications require higher data throughput in future (i.e. broadband access). For this purpose, the current defence use of HF/VHF communications might not be suitable, and so requirements may arise to fulfil this demand for mobile broadband in other bands (such as 700 MHz).

As an illustration of this demand, it is envisaged that the third generation of the UK's Network Enabled Capability for Close Combat project would operate at up to 6Mbit/s (compared with 40kbit/s today,[35] corresponding to a ~150-fold increase in peak requirements). This would potentially require a significant number of wireless channels. We note that it has been suggested that there could be synergies between this technology trend and the potential need for a PPDR broadband network (see Section 5.10.1).

To ensure defence-level security of mobile data traffic, higher bandwidth is likely to be required than that used for equivalent civilian mobile broadband; this reflects the spectral cost of secured and classified transmission. There is also likely to be increased demand for satellite communications, and a requirement for spectrum access for ad-hoc and mesh networks.

Overall, this new technology trend could lead to a significant increase in spectrum usage demand from the defence sector.

5.4.2 Positioning and navigation

Technology trend	Short term	Mediu m term	Long term
Positioning and navigation	=	=	=

Figure 5.34: Assessment of the impact of positioning and navigation on spectrum usage demand [Source: Analysys Mason, 2013]

This trend includes airfield navigation and surveillance enablers, airborne navigation aids, maritime navigation aids and GNSS. Technology trends in this area over the next ten years are likely to be gradual and will have synergies with civilian aeronautical applications, such as RPAS. Furthermore, many frequencies that are used for aeronautical navigation purposes are internationally harmonised for use across the whole aviation sector, so demand for these is unlikely to change.

The GNSS Supervisory Authority (GSA) is currently carrying out a number of research activities looking at how GNSS receivers might be combined with terrestrial radio equipment.

35 Largely for voice applications.

5.4.3 Detection and radar improvements

Technology trend	Short term	Medium term	Long term
Detection and radar improvements	=	=	=

Figure 5.35: Assessment the of impact of detection and radar improvements on spectrum usage demand [Source: Analysys Mason, 2013]

The defence sector uses radars for a wide range of applications such as coastal, air and space surveillance, long-range and early warning surveillance, air defence, imaging and SRD. Each of these applications has different radar characteristics and therefore uses different spectrum bands (from HF to the Ka-band). Furthermore, the suitable frequency band and bandwidth are determined by the required performance (for example, whether the requirement is detection through clouds, forest or walls).

As with civilian aviation and maritime applications, a number of radar improvements are being researched: these include passive radar and multi-static radar, new signal processing techniques and new waveforms (as explored in more detail in Section 5.1.2). While all of these radar improvements have the potential to deliver a more efficient use of spectrum, it is likely that available spectrum will be used to improve performance detection or resolution.

5.4.4 Information acquisition

Technology trend	Short term	Medium term	Long term
Information acquisition	+	+	+

Figure 5.36: Assessment of the impact of information acquisition on spectrum usage demand [Source: Analysys Mason, 2013]

This technology trend involves acquiring strategic information through the use of radio frequency (RF) sensors. This information could include intelligence, satellite or airborne imagery. Spectrum access is also required for the networking of sensors and for advanced acquisition processes. These technologies largely overlap with the aeronautical, meteorological and space sectors (e.g. Agenda Item 1.12 of WRC-15).[36]

As with radar detection, frequency band and bandwidth are often determined by the required performances.

36 *"To consider an extension of the current worldwide designation to the Earth exploration-satellite (active) service in the frequency band 9 300-9 900 MHz by up to 600 MHz within the frequency bands 8 700-9 300 MHz and/or 9 900-10 500 MHz"* – see ECC report ECC CPG15 - CPGPTA(2012)024 Annex 9

5.5 Fixed links (Fixed)

The fixed links category involves the use of point-to-point microwave links. These links are used for a broad range of applications, one of the most common being the provision of backhaul for mobile base stations. The technological advances which will have an impact on spectrum requirements are varied and are discussed in more detail in the following sections.

Overall, as shown in Figure 5.37, our impact assessment on future demand for spectrum for fixed links will mainly depend on:

- the migration to higher-frequency fixed links
- the degree of substitution by fibre networks, which is likely to vary significantly between and within countries, based on the degree of urbanisation and affordability of fibre.

Figure 5.37: Summary of fixed links technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Use of wider channels / higher frequencies	– –	– –	– –
Improved modulation techniques	–	–	–
Use of cross-polarisation interference cancellation (XPIC)	–	–	–
NLoS/QLoS backhaul	+	+	+
Zero-footprint units	=	=	=
Other technology advances	=	=	=
Fibre substitution	– –	– –	– –
OVERALL ASSESSMENT	–	–	–

5.5.1 Use of wider channels / higher frequencies

Technology trend	Short term	Medium term	Long term
Use of wider channels / higher frequencies	– –	– –	– –

Figure 5.38: Assessment of the impact of the use of wider channels / on spectrum usage demand higher frequencies [Source: Analysys Mason, 2013]

As demand for backhaul data grows (e.g. with the introduction of LTE), the requirement for wider channels is becoming increasingly important. Ongoing R&D aims to address this, for example by doubling channel sizes or by creating contiguous channels. The increasing demand for spectrum means that most links are migrating towards higher frequencies (above 6 GHz, and increasingly above 40 GHz), with standards now existing for up to 100 GHz; links below 6 GHz are thus becoming increasingly rare. Therefore, although overall demand is growing, usage below 6 GHz is likely to fall.

Some users of fixed links are aware of the EC initiative to review the 400 MHz–6GHz band and so are looking to migrate to higher frequencies in the medium term. However, it should be noted that lower-frequency links are still cheaper to use, as higher-frequency chipsets are expensive. It may be easier for some parties to move to higher frequencies than others – for example, we understand that one Italian broadcaster relies heavily on long-range links at 3.6 GHz.

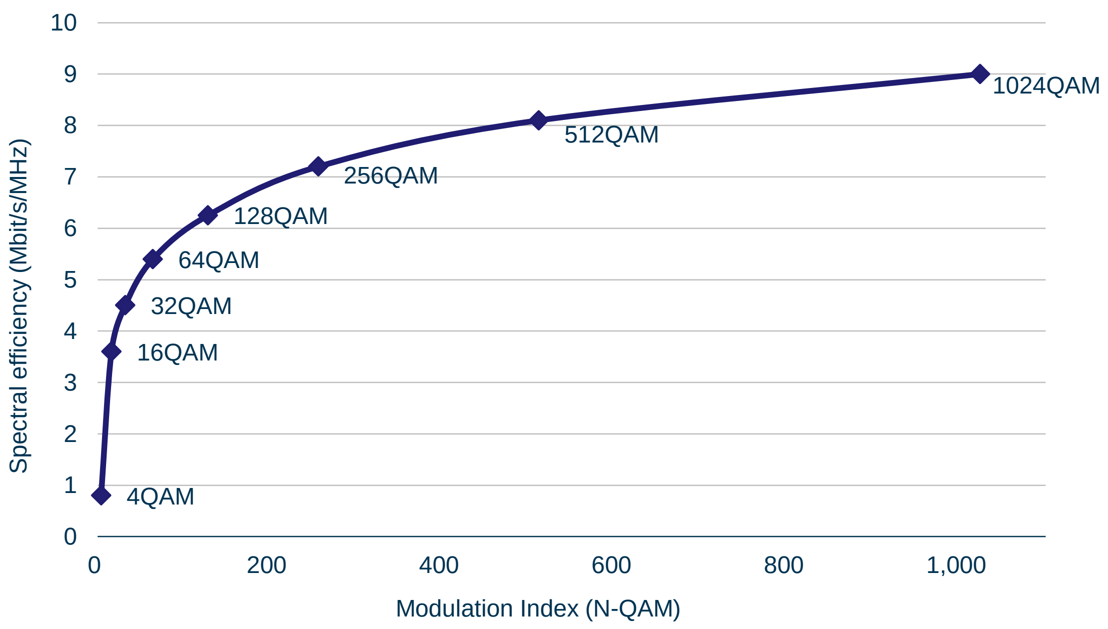
5.5.2 Improved modulation techniques

Technology trend	Short term	Medium term	Long term
Improved modulation techniques	–	–	–

Figure 5.39: Assessment of the impact of improved modulation techniques on spectrum usage demand [Source: Analysys Mason, 2013]

Advances in modulation schemes and coding (error correction) will allow for higher spectral efficiency for point-to-point links. These schemes, based on QAM (as discussed in the context of mobile in Section 5.3.1 and in detail in Annex B), support greater capacity as the modulation index increases. Figure 5.40 below shows how spectral efficiency improves with an increase in the modulation index; however, it can be seen that the achievable incremental improvement in spectral efficiency decreases for each increase in modulation index.

Figure 5.40: Variation in efficiency with modulation index [Source: ECC Report 173, Analysys Mason, 2012]



This decrease in incremental benefit with increasing modulation index is further compounded by the need for more error correction codes; this will ultimately be the limiting factor on the level at which modulation can enhance spectrum efficiency. The latest equipment has the ability to use modulation schemes of 512-QAM and 1024-QAM, but an increase in the index above 1024-QAM is unlikely to occur given the need for more redundant error correction codes.

Adaptive modulation which adjusts the modulation scheme based on demand (both quantity and quality) will increase the efficiency of spectrum use. This comes as a corollary to increasing modulation index, enabling the level of modulation to be altered in accordance with both the specifications of the application and also the external conditions. In essence, high modulation schemes can be used in situations where there is a need for high quality or capacity, as well as favourable propagation conditions. Conversely, under poor propagation conditions the modulation index can be reduced to ensure the continuity of the signal, and that data transmitted is not lost.

Overall, if we assume that 256-QAM is the most widespread modulation scheme currently in place, then the theoretical spectral efficiency gain would be ~13% if 512-QAM were to be employed, or ~25% for 1024-QAM. This could therefore provide a reduction in spectrum usage demand. We note that one complication of adaptive modulation is that it can create traffic planning challenges if deployed over large microwave networks.

5.5.3 Use of XPIC

Technology trend	Short term	Medium term	Long term
Use of XPIC	–	–	–

Figure 5.41: Assessment of the impact of use of XPIC on spectrum usage demand [Source: Analysys Mason, 2013]

Increased use of XPIC can double the capacity in a co-channel dual-polarisation (CCDP) application. This is already a well-established technology but it is now becoming more widespread, and so could potentially provide a reduction in spectrum usage demand in the medium term.

5.5.4 NLoS / QLoS backhaul

Technology trend	Short term	Medium term	Long term
NLoS / QLoS backhaul	+	+	+

Figure 5.42: Summary of impact of NLoS / QLoS backhaul [Source: Analysys Mason, 2013]

NLoS / QLoS backhaul is a technique that could potentially be employed to provide backhaul for pico-cells. The propagation characteristics of lower frequencies (i.e. below 6 GHz) are likely to be desirable for this application; indeed, commercially available equipment appears to use bands in the range 2.3–3.6 GHz. An envisaged use of this technology is for small cells at street level, although in urban areas it is likely that fibre will be present, which would be a preferred method of backhaul in most cases. However, purely in terms of technology trends, this is a new application which would lead to an increase in spectrum usage demand.

5.5.5 Zero-footprint units

Technology trend	Short term	Medium term	Long term
Zero-footprint units	=	=	=

Figure 5.43: Assessment of the impact of zero footprint units on spectrum usage demand [Source: Analysys Mason, 2013]

Zero-footprint units are a new form of small, low-cost radio, which may be useful for delivering broadband links to rural areas where it is not economically viable to lay fibre, or where copper does not already exist. Lower-frequency chipsets will be the cheapest, but are still likely to operate at well above 6 GHz.

The units are likely to be most useful in Member States where a high proportion of the population lives in rural areas, such as Ireland. Overall, due to the bands that these zero-footprint units will probably use, this technology trend is unlikely to have an impact on spectrum usage demand between 400 MHz and 6 GHz.

5.5.6 Other technology advances

Technology trend	Short term	Medium term	Long term
Other technology advances	=	=	=

Figure 5.44: Assessment of the impact of other technology advances on spectrum usage demand [Source: Analysys Mason, 2013]

Other potential fixed-link trends include header compression, smaller dish sizes and synchronisation improvements. Whilst these improve system performance, they are only really relevant to higher frequencies, and so will have no impact on spectrum between 400 MHz and 6 GHz.

5.5.7 Fibre substitution

Technology trend	Short term	Medium term	Long term
Fibre substitution	– –	– –	– –

Figure 5.45: Assessment of the impact of fibre substitution on spectrum usage demand [Source: Analysys Mason, 2013]

As fibre connections become more common in future, they will increasingly replace fixed links as a method of providing network backhaul. Indeed, where possible and economically feasible, mobile network operators and tower companies are already focusing on this development.

Although not strictly a new technology, this trend still represents a potentially significant change in spectrum usage for this category. As fibre deployment continues, fixed-link spectrum usage is likely to fall – although the extent of this trend will vary significantly both between and within countries, depending on fibre availability. Fixed links will probably remain in certain areas where fibre is unlikely to be implemented, for example in rural communities.

5.6 Intelligent transport systems (ITS)

Intelligent transport systems are, to some extent, already in operation in Europe, although their deployment is largely uncoordinated among Member States. The overall aim is to have a co-operative and unified framework of systems working across Europe. This framework would enable the deployment of several component technologies, with a view to achieving advances in areas such as safety, congestion, toll collection and driver assistance.

Overall, as shown in Figure 5.46, our impact assessment on future spectrum usage demand for ITS will mainly depend on the take-up and usage of new applications and technologies that are developed.

Figure 5.46: Summary of ITS technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
New applications	=	=	=
Vehicle-to-vehicle communications	+	+	+
Rail application	=	=	=
OVERALL ASSESSMENT	**=/+**	**=/+**	**=/+**

5.6.1 New applications

We have identified a number of applications which use existing technologies such as GNSS and cellular data to provide new intelligent services relevant to the ITS sector, as shown in Figure 5.47.

Technology trend	Short term	Medium term	Long term
Real-time traffic services	=	=	=
e-freight	=	=	=
eCall	=	=	=

Figure 5.47: Assessment of the impact of future systems on spectrum usage demand [Source: Analysys Mason, 2013]

Real-time traffic services

This system or collection of systems would allow for constant communication not just between vehicle and road, but also between vehicles. This communication, and the information shared, would create a more pro-active road network. The benefits arising from this would be reduced congestion, and hence lower emissions and less impact on the environment.

In fact, a real-time traffic service would be implemented using a collection of various current technologies, and is likely to be met by existing mobile or radio broadcasting spectrum designations. Therefore, this technology trend is likely to a have limited impact on spectrum usage demand.

e-freight

This is a system by which the transport of goods, as well as the information pertaining to that transport, become fully available in a secure, pan-European and real-time fashion.

As with real-time traffic services, the system would be implemented using a collection of various existing technologies. Therefore, the wireless needs are likely to be met by existing mobile or radio broadcasting spectrum, which is already designated, thus having a limited impact on spectrum usage demand.

eCall

eCall is an in-vehicle emergency call system and will be one of the main systems used in European ITS. The EC's aim is that eCall will eventually be installed in all new vehicles, and in 2011 it started the EU-wide Harmonised eCall European Pilot (HeERO) project to kick-start this initiative.

However, eCall is likely to use existing commercial mobile networks, and so will have a limited impact on spectrum demand beyond that currently designated.

5.6.2 V2V communication systems

Technology trend	Short term	Medium term	Long term
V2V communication systems	+	+	+

Figure 5.48: Assessment of the impact of V2V communication systems on spectrum usage demand [Source: Analysys Mason, 2013]

V2V communications systems aim to improve road safety by allowing vehicles to communicate with other vehicles and with road-side infrastructure. Such systems are likely to build on existing technologies such as radar-guided cruise control, to give vehicles an intelligent understanding of the location and nature of other vehicles nearby.

The concept of inter-vehicle communications is a new technology, and so would require spectrum, most likely in the 5.9 GHz band; in the USA, 75 MHz has been designated for 'dedicated short-range communications', which includes V2V communication.

In light of the significant R&D efforts that car manufacturers and some other organisations are making to improve vehicle safety, it is likely that this area will develop continually over the coming years. However, because of the safety aspects that are at stake, and the controversy surrounding emerging 'driverless vehicle' technologies, it is likely that the impact on spectrum usage demand will also be dependent on policy decisions (both in terms of spectrum and transport safety). Therefore, the reliance on policy developments and continuing R&D in the sector is most likely to result in an increase in spectrum usage demand in the longer term.

5.6.3 Rail applications

Technology trend	Short term	Medium term	Long term
European traffic control system (ETCS)	=/+	=/+	=/+
European Rail Traffic Management System (ERTMS)	=	=	=
Other ITS for railways	=	=	=

Figure 5.49: Assessment of the impact of rail applications on spectrum usage demand [Source: Analysys Mason, 2013]

ETCS

ETCS is the new standard of rail traffic management which is gradually being rolled out across Europe and currently covers 7000km of track. As this is a relatively low-bandwidth application whose deployment is expected to take many years, it is expected to have a modest impact on spectrum usage, and in the medium term is likely to use existing GSM-R designations. The system currently uses circuit-switched links over GSM-R, but a move to packet-switched transmission is envisaged by 2014–2015.

There are four levels of ECTS (0–3) with the highest level consisting of no physical signalling along the track and the possibility of virtually driverless trains. Therefore, the criticality of a resilient radio network becomes more important as ECTS becomes more advanced.

ERTMS

ERTMS is an initiative backed by the EC to enhance cross-border interoperability, as well as the procurement of signalling equipment by creating a single Europe-wide standard for train control and command systems. While cross-border co-ordination is fairly advanced in Europe's rail networks, some Eastern European Member States still use rail communications frequencies for defence, which raises issues when trains cross borders.

ERTMS has two main components: ETCS (discussed above) and GSM-R. GSM-R is the GSM mobile communications standard for railway operations; working within the GSM sub-band 876–880 MHz, it provides communications services, both voice and data, for rail network operators.

At present, wireless rail applications require fairly low bandwidth, but as the deployment of new technology continues and data demands grow, it is likely that there will be a requirement for a new network, designed for data transport. However, GSM-R's replacement is unlikely to be implemented until 2027, with development of GSM-R halting around 2020. LTE would appear to be the likely successor to GSM-R, and it is possible that for this next generation stakeholders will not wish to develop a new standard that is unique to rail services. Given the expected timescales, ERTMS is unlikely to have an impact on spectrum usage demand within the time horizon of this study.

Other ITS for railways

Key applications include radar (which is currently migrating from 24 GHz to 77 GHz) and Balise/Euroloop, which are wireless transponders that are integrated within the railway track:

- Balise senses the presence of a train via a 27 MHz oscillation, and communicates back at 7 MHz
- Euroloop is a similar system which uses 23 MHz and 7.3 MHz for the same applications, respectively.

As all of these new developments are above 6 GHz or below 400 MHz, they are expected to have no impact on spectrum range considered in this study.

5.7 Meteorology (MET)

Meteorology is heavily reliant on spectrum for weather forecasting, and other related applications such as monitoring climate change. The main uses of spectrum are for radars (which are used to detect precipitation and profile wind patterns) and satellite networks such as EUMETSAT (which are able to monitor Europe-wide or global weather patterns). Because of meteorology's dependence on radar, most of the meteorology spectrum bands are required due to their physical characteristics, such as the wavelengths being suitable for back-scattering off rain showers.

Any technological developments are therefore likely to focus on increasing the performance of the bands that are already used, in order to make further improvements to weather forecasting. It seems unlikely that there will be significant demand for new spectrum over the next ten years. It should be stressed that the spectrum already used for meteorology is vital to the operations of these services.

Figure 5.50: Summary of MET technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Satellite services	=	=	=
Radar improvements	=	=	=
OVERALL ASSESSMENT	**=**	**=**	**=**

5.7.1 Satellite services

Technology trend	Short term	Medium term	Long term
Satellite services	=	=	=

Figure 5.51: Assessment of the impact of satellite services on spectrum usage demand [Source: Analysys Mason, 2013]

It is envisaged that the third generation of EUMETSAT satellites will have a downlink operating at between 7 GHz and 8 GHz, with the first satellite expected to be launched around 2020. This development is therefore outside the scope of this study, in terms of both the spectrum bands considered and the time horizon. We note that these satellite meteorology services need to be harmonised at EU level or globally.

As EUMETSAT operates a large fleet of satellites, it requires of range of frequencies; in terms of bandwidth usage between 400 MHz and 6 GHz, around 102 MHz is used for forward links and around 105 MHz for return links.[37] The current generation of satellites is expected to operate alongside the next generation for some period of time, and so it is unlikely that spectrum usage below 6 GHz will be reduced in the next ten years.

5.7.2 Radar improvements

Technology trend	Short term	Medium term	Long term
Radar improvements	=	=	=

Figure 5.52: Assessment of the impact of radar improvements on spectrum usage demand [Source: Analysys Mason, 2013]

As previously mentioned, the frequency bands used for meteorology radars are restricted by the physics of the atmospheric events that need to be monitored. The main radar uses are as follows:

- Wind profiler radars work by firing radiation in the 915–917 MHz and/or 1270–1290 MHz bands vertically, and measuring small amounts of reflected power that are backscattered by atmospheric turbulence.
- Precipitation sensing and Doppler wind information is gathered using horizontal radars in the 2.7–2.9 GHz and 5.6–5.65 GHz bands. Some Member States have encountered interference issues with radars in this latter band, possibly due to 5 GHz Wi-Fi devices.

The focus of any improvements to these technologies is therefore likely to be on enhancing the performance of existing radar bands, and reducing the susceptibility to interference. In this case, there may be a need for re-designation of frequencies rather than an increase in spectrum demand.

5.8 Private mobile radio / public access mobile radio (PMR/PAMR)

PMR includes not only the underlying radio network of base stations, but also the handheld, console or mobile radio devices which require the use of licensed spectrum. This category is closely linked to the PPDR category (see Section 5.10 below), as many PPDR communications systems involve applications of PMR/PAMR technologies. We also note that there is demand from the utilities sector for spectrum in the 450–470 MHz band, for example for smart metering – see Section 5.8.2, which is currently used for PMR in many Member States.

Overall, as shown in Figure 5.53, we believe that digital replacements (the core technology trend we have identified in relation to PMR) will have a negligible impact on overall spectrum usage demand by PMR. However, our impact assessment on future demand for spectrum from this category will depend on the extent to which the efficiency of new PMR technology outweighs the effect of more-demanding applications, as well as the increased deployment of smart grids and smart meters.

[37] *EUMETSAT use of different frequency bands and related services*, 2010 – see ftp://ftp.eumetsat.int/pub/CPS/out/CGMS%2038%20report/CGMS-38%20CD/Working%20Papers%20CGMS-38/EUMETSAT/CGMS-38%20EUM-WP-23.pdf

Figure 5.53: Summary of PMR technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Digital replacements	–/=	–/=	–/=
Smart grids and smart metering	++	++	++
OVERALL ASSESSMENT	**=/+**	**=/+**	**=/+**

5.8.1 Digital replacements

Technology trend	Short term	Medium term	Long term
Digital replacements	–/=	–/=	–/=

Figure 5.54: Assessment of the impact of digital replacements on spectrum usage demand [Source: Analysys Mason, 2013]

Analogue PMR equipment remains widespread across Europe; however, emerging digital PMR systems are likely to make more efficient use of existing spectrum than the previous generation of analogue systems. A number of digital standards exist, with TETRA at the higher end of the market being well-established worldwide. The digital mobile radio (DMR), digital private mobile radio (dPMR) and NXDN standards tend to be used for smaller networks, although systems currently coming to market based on the DMR standard are able to support regional networks. The take-up of lower-cost, lower-end digital equipment has been slow, but this is currently accelerating as existing analogue equipment becomes obsolete.

DMR allows two speech paths in a single 12.5 kHz channel; dPMR can also have two speech paths using a 12.5 kHz FDMA channel, and may offer more potential for reducing spectrum usage demand than DMR. However, at this stage it appears that TETRA and DMR – two of the ETSI[38] mobile radio standards – are likely to be the most mainstream digital PMR technologies over the next ten years.

Most of the digital standards support low-bandwidth data usage (in particular short data messaging) over PMR equipment, but as with the additional voice channels per carrier, there may be challenges determining the overall added digital efficiency. The impact on spectrum usage demand will therefore be dependent both on usage trends (users may still wish to use these more spectrally efficient technologies for data traffic or for more voice channels), as well as on overcoming the challenges of sharing any spectrum that is made available through the use of this more spectrally efficient equipment.

Overall, there is potential for gains in spectral efficiency to bring a reduction in spectrum usage demand, although additional demand is likely to cancel out the gains.

38 European Telecommunications Standards Institute

5.8.2 Smart grids and smart metering

The utilities sector is likely to become increasingly reliant on wireless technologies over the next ten years, with development and implementation taking place in a number of areas (such as smart grids and smart metering) which will enhance the intelligence of electricity, water and gas distribution networks. It is also becoming increasingly important for utility companies to invest in smarter, more efficient distribution networks in order to meet the EU's 2020 Climate and Energy targets,[39] including:

- a 20% reduction in EU greenhouse gas emissions from their 1990 levels
- raising the share of EU energy consumption that is produced from renewable resources to 20%
- a 20% improvement in the EU's energy efficiency.

Technology trend	Short term	Medium term	Long term
Smart grids and supervisory control and data acquisition (SCADA)	++	++	++
Smart metering	+	+	+

Figure 5.55: Assessment of the impact of smart grids and smart metering on spectrum usage demand [Source: Analysys Mason, 2013]

Smart grids and SCADA

The concept of SCADA is a fundamental constituent of a smart grid, whereby the grid is monitored and controlled using an array of sensors and switches throughout the grid. SCADA is important for all types of utility:

- in electricity grids, it is used to monitor factors such as voltage, current and temperature, and can be used to adjust the grid in response to variations in demand, or in the event of a fault occurring
- it is used to monitor and control gas networks, ensuring that they are kept at the optimum pressure (high enough to regulate distribution but low enough to reduce the likelihood of leaks)
- SCADA is used in water distribution systems to control the pressure of water and reduce the likelihood of leaks. It is also used throughout water networks for monitoring and controlling the supply of fresh water, as well as the removal of waste.

Clearly, all sensors and switches that are used for SCADA need to be connected to the grid control centre. In some cases, it might be possible to do this using fixed connections, but in many other cases wireless links are required (such as in remote areas). For some mission-critical fault detection applications, fixed links are used due to their low latency (i.e. for teleprotection applications – see Section 5.5.6); overall, however, this application appears to require additional spectrum. It is highly unlikely that commercial networks would be suitable for SCADA applications, as this sort of open access would pose a national security risk to the critical infrastructure. Indeed, it is widely considered that SCADA networks should be physically separate from the Internet, to minimise the risk to national security.

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39 See http://ec.europa.eu/clima/policies/package/index_en.htm

Smart metering

There is a growing trend towards smart metering, whereby the utility meter installed in consumer premises is a piece of electronic equipment that is connected to the utility service provider. As part of an energy saving and carbon reduction initiative, the EC is mandating the roll-out of such equipment across Europe. The target is to install smart meters in at least 80% of European households by 2020, with the following anticipated outcomes:

- more frequent updates of meter readings provided directly to the consumer, which may give consumers further incentives to save energy and therefore money
- meters would store data, enabling consumers to view usage data and patterns to help them make decisions on future energy use
- the ability for the service provider to read meters remotely, which could provide sufficiently detailed and frequent data to help it plan future network expansion
- the ability for service providers to optimise energy pricing structures and potentially offer consumers the option to change their tariffs remotely.

As latency is not a major issue for smart meters, and the required data rates are low, many smart meters currently use commercial mobile networks (for example, the GPRS network) to communicate with the utility service provider. However, it is unclear whether demand for dedicated spectrum for this purpose will emerge as smart meters become more widespread. Although the required data rates are low (<10kbit/s), in order to have the best impact on energy planning, meter data may need to be uploaded every few minutes, resulting in a large amount of data traffic overall. Furthermore, commercial networks are generally provisioned to optimise the downlink capacity, whereas this application is likely to be asymmetric in the opposite direction. As a result, work is currently underway by the ECC to make the 870–876MHz band available for smart metering applications as well as the 169 MHz band.

Summary

Overall, it appears that there will be an increase in demand for spectrum from the utilities sector for the provision of smart grids and smart metering over the next ten years. In terms of frequencies, utilities stakeholders claim that the 450–470 MHz band would be the most suitable for smart grid applications, but this band is likely to be too congested to accommodate 15 MHz of new spectrum needed for the applications listed above. Therefore, 5 MHz in this band supplemented by 10 MHz in the 1–2 GHz band might be a more feasible approach.

5.9 Programme making and special events (PMSE)

The PMSE category consists of all technologies and applications required for staging live events, as well as for making TV programmes and films. Spectrum use therefore largely consists of audio and video links from cameras and microphones respectively, to the production team. PMSE spectrum is generally heavily used and is known to be highly congested, particularly in areas close to theatres or TV studios, such as in the West End of London. Recently, events such as the London 2012 Olympic Games have made innovative and impressive use of PMSE technology and spectrum, casting a spotlight on the sector.

Overall, as shown in Figure 5.56, our impact assessment on future spectrum usage demand for PMSE will mainly depend on the level of adoption of microphones and HD cameras.

Figure 5.56: Summary of PMSE technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Digital microphones	=	=	=
Higher-frequency wireless cameras	=	=	=
Adoption of 3D/HD cameras	++	++	++
Mobile broadcast systems	+	+	+
OVERALL ASSESSMENT	**=/+**	**=/+**	**=/+**

5.9.1 Digital microphones

Technology trend	Short term	Medium term	Long term
Digital microphones	=	=	=

Figure 5.57: Assessment of the impact of digital microphones on spectrum usage demand [Source: Analysys Mason, 2013]

Currently, the PMSE industry broadly relies on analogue microphones for the amplification and recording of sound. The adoption of digital microphones has been gradual due to latency issues, meaning that analogue technology is still better suited to live events. This is because there is an inherent delay involved in picking up an analogue (voice) signal, converting it into a digital signal for transmission, and then converting it back into an analogue signal for input into a loudspeaker or amplifier.

Individually, new digital microphones may be no more spectrally efficient than analogue ones. However, Qualcomm has demonstrated units that use orthogonal frequency-division multiple access (OFDMA), which would allow microphone channels to be much more dense, thus enabling many more digital microphones to operate in a block of spectrum than would be possible with analogue systems. However, this does require a contiguous block of spectrum to be available, which might not always be the case. There are also likely to be issues with the power consumption of these units.[40] One further challenge is that currently, using digital microphone equipment can be significantly more expensive than using analogue equipment, which could represent an issue for a sector which does not always have access to abundant resources.

Clearly, significant technological advances will be required for digital microphones to become widespread, with some manufacturers only recently announcing digital microphone chipsets which are capable of latency closer to that of analogue systems, using a similar bandwidth. As a result, there is a general concern within the PMSE sector regarding the adoption of digital microphones, and it is likely that analogue systems will remain the norm for some time.

40 See http://www.marcus-spectrum.com/Blog/files/b6610ee4fe16b2c5effe788cbe718840-155.html

5.9.2 Higher-frequency wireless cameras

Technology trend	Short term	Medium term	Long term
Higher-frequency wireless cameras	=	=	=

Figure 5.58: Assessment of the impact of the adoption of higher-frequency wireless cameras on spectrum usage demand [Source: Analysys Mason, 2013]

Wireless cameras which transmit at a higher frequency (e.g. 7.5 GHz) are becoming more and more common; historically, cameras tended to use lower frequencies such as the 2 GHz and 3 GHz bands. Because these newer cameras operate above 6 GHz, a migration to these devices would lead to a reduction in spectrum usage demand in the bands being considered by this study.

However, lower-frequency cameras are particularly advantageous for some uses: they are more suitable for NLoS applications, as well as for high-speed applications (e.g. for on-board motorsports cameras). Increased demand for PMSE spectrum has resulted in more cameras needing to use higher frequencies, and we note that the uncertainty over which bands may be made available for PMSE could be delaying equipment development.

In reality, it is likely that both types of wireless camera will be used in a complementary fashion. This technology trend is therefore likely to have a limited impact on spectrum usage demand up to 6 GHz, provided there is no migration effect within the timescale considered by this study.

5.9.3 HD / 3D cameras

Technology trend	Short term	Medium term	Long term
Adoption of HD/3D cameras	++	++	++

Figure 5.59: Assessment of the impact of HD / 3D cameras on spectrum usage demand [Source: Analysys Mason, 2013]

Most wireless cameras are now HD-equipped, and 3D wireless cameras are increasingly being used to cover major sporting events. 3D wireless cameras currently require two 10 MHz channels to transmit 'two-picture' 3D coverage, thus doubling the amount of bandwidth required per camera. We believe that equipment manufacturers are currently working to optimise the wireless coding used in 3D cameras, so that the 3D transmission fits within existing 10 MHz channels, but it is unclear how long this development work will take. Currently, manufacturers appear to be making HD wireless transmission systems which work at a range of frequency bands, from ~1 GHz up to 7 GHz.

5.9.4 Mobile broadcast systems

Technology trend	Short term	Medium term	Long term
Mobile broadcast systems	+	+	+

Figure 5.60: Assessment of the impact of mobile broadcast systems on spectrum usage demand [Source: Analysys Mason, 2013]

The PMSE sector is increasingly using innovative methods to transmit wireless signals between the cameras at a live event and the production team, typically for broadcasting purposes. This involves creating an ad-hoc, mobile microwave transmission network, possibly using vehicles such as motorbikes and helicopters. An application of this kind was used during the London 2012 Olympic Games, to broadcast events such as the cycle road race. Having cameras mounted on cars and motorbikes allowed the flexibility of mobile filming, with the backhaul being sent by microwave to an overhead helicopter, which was able to relay the signal to a production van. This approach allows the use of PMSE spectrum bands to be confined geographically, so that the same bands can be re-used in other locations.

5.10 Public protection, disaster relief (PPDR)

PPDR mobile communications have been based on PMR technologies, such as the TETRA or Tetrapol networks which are used by the majority of police organisations in Europe for communications. PPDR applications also make use of other services and bands, such as satellite communications for operations in remote areas, or the increasing trend of integrating GNSS receivers into PPDR communications equipment.

Trends will change in future, with the recognised need to support more data-intensive applications for PPDR organisations. The need for a broadband data network, dedicated to mission-critical applications is under consideration across Europe; and is already being implemented in the USA. Furthermore, it could also be argued that there is a greater need for interoperability between different PPDR networks, as well as between PPDR networks and commercial networks. Interoperability on a global scale would also be advantageous for services such as cross-border and international rescue operations.

Overall, as shown in Figure 5.61, our impact assessment on future demand for spectrum for PPDR will mainly depend on:

- the need for mission-critical high-speed data networks; either a new mobile broadband network, or an upgrade to the data capability of existing TETRA networks (i.e. TEDS)
- the potential for PPDR services to share commercial networks.

Figure 5.61: Summary of PPDR technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
PPDR high-speed data network	=/+	+	++
Use of commercial networks	–/=	–/=	–/=
TETRA 2 (TEDS)	=/+	+	+
OVERALL ASSESSMENT	**=/+**	**=/+**	**=/+**

5.10.1 PPDR high-speed data network

Technology trend	Short term	Medium term	Long term
PPDR high-speed data networks	=/+	+	++

Figure 5.62: Assessment of the impact of PPDR high-speed data networks on spectrum usage demand [Source: Analysys Mason, 2013]

Multimedia applications are expected to become commonplace for PPDR use in the future to support mission-critical operations; for example, thermal imaging and 3D video forensics. Due to this forecast increasing use of data applications, PPDR stakeholders agree that a PPDR mobile broadband network is required for critical infrastructure use. Estimates of the spectrum required to support a dedicated mission-critical network (possibly using LTE as the underpinning technology) range from 2×10 MHz to 2×20 MHz in a suitable band (such as 700 MHz). Some work is already underway to adapt LTE for PPDR use; for example, some public safety services in the USA plan to migrate their voice and data services to an LTE network.

Emergency services use commercial networks alongside private networks for non-mission critical data-intensive applications. These systems are not currently deemed to be resilient enough for mission-critical use; for example, the UK police force has deployed over 40 000 BlackBerry devices, but these solutions are of limited use in the rare event of network or provider outages.

While there will be ongoing development and testing of systems to support mission-critical broadband data systems, it is difficult to say when implementation might occur, with one major hurdle being the availability of a harmonised PPDR spectrum designation to support such systems. If spectrum is designated, then a mission-critical PPDR network could come online creating an increase in spectrum usage demand within the PPDR category.

This technology trend may have synergies with the connected equipment envisaged for the defence sector. In addition, because of the nature of the devices required for both defence and PPDR purposes (i.e. toughened and hard-wearing, unlike mass-consumer equipment), there could be potential for the co-procurement of these devices.

5.10.2 Use of commercial networks

Technology trend	Short term	Medium term	Long term
Use of commercial networks	–/=	–/=	–/=

Figure 5.63: Assessment of the impact of use of commercial networks on spectrum usage demand [Source: Analysys Mason, 2013]

There is a case (largely justified by potential cost savings) that rather than having standalone PPDR networks, critical services should find ways of using existing commercial networks. If this were to be implemented, and proven capable of supporting both voice and data functionality, then the existing TETRA spectrum would no longer be required. However, because of the critical dependence on high network reliability for PPDR, there are a number of challenges that must first be overcome.

As previously mentioned, PPDR bodies do already use commercial networks for non-mission critical applications; however, it appears clear that these networks are currently unsuitable for mission-critical applications. For example, commercial mobile networks may become overloaded during emergency situations, or in the case of power supply discontinuity lose service altogether, which would cause severe problems to PPDR services and to law and order in general.

Some bodies are carrying out work to develop this technology trend. In Belgium, for example, the TETRA operator Astrid is setting up a secure mobile virtual network operator (MVNO) on a commercial network to accommodate PPDR users. This will focus on data services (including the use of LTE where available) in the short to medium term, supporting the current TETRA provision rather than replacing it.

Overall, the potential use of commercial network spectrum for PPDR services would mean a reduction in specific spectrum usage, if a feasible solution could be found.

5.10.3 TETRA 2 (TEDS)

Technology trend	Short term	Medium term	Long term
TETRA 2 (TEDS)	=/+	+	+

Figure 5.64: Assessment of the impact of TETRA 2 (TEDS) on spectrum usage demand [Source: Analysys Mason, 2013]

TETRA enhanced data services (TEDS) is a part of the TETRA 2 standard, and requires additional spectrum (ideally 2×5 MHz within the 380–400 MHz band) to be implemented. TEDS has not been widely adopted in Europe, in part because in many cases the spectrum has not been designated for it, stifling take-up and impacting the funding of ongoing R&D.

TEDS provides data services with similar performance to that of GPRS, so stakeholders may see it as ‘too little too late’ and choose not to invest in the additional network roll-out and spectrum that would be required. However, some organisations still see TEDS as a useful service; for example, TEDS is in small-scale deployment in Finland, and in Norway it is currently being tested ahead of the potential roll-out to limited areas of the country.

If TEDS is more widely implemented, there will clearly be a slight increase in spectrum usage demand. However, if it does not take off, this trend will have a limited impact.

5.11 Radio astronomy (Science)

The science category consists of radio astronomy (space research and space operations), as well as educational and university use of spectrum. However, the main technology trends that have been identified for this category relate to radio astronomy.

In the same way as optical telescopes passively absorb light being emitted from other regions of space, radio astronomy telescopes typically involve the use of large radio receivers to listen for electromagnetic waves outside the visible spectrum.

As with the meteorological category, the spectrum bands required for radio astronomy purposes are dependent on the physical characteristics of frequencies that are of interest to the sector. Radio telescopes do not generally transmit and so are passive ‘listening’ devices. However, as they are attempting to detect very weak radio sources that could originate many millions of light years from earth, radio telescopes are incredibly sensitive devices. As such, they may have ‘transmit exclusion zones’ around them, to protect them from interference from terrestrial devices, and radio astronomy frequency designations may be made on a geographical basis.

Overall, our impact assessment is that demand for spectrum due to technology trends in the science category is likely to remain relatively constant over the next ten years, assuming the sector does not encounter issues with interference stemming from the use of newly designated spectrum by applications in other categories.

Figure 5.65: Summary of science technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
More powerful back-end processing	=	=	=
Very long baseline interferometry (VLBI)	=	=	=
OVERALL ASSESSMENT	**=**	**=**	**=**

5.11.1 More powerful back-end processing

Technology trend	Short term	Medium term	Long term
More powerful back-end processing	=	=	=

Figure 5.66: Assessment of the impact of more powerful back-end processing on spectrum usage demand [Source: Analysys Mason, 2013]

The use of more powerful back-end systems that are able to process higher bandwidths means that even single-dish telescopes can detect and measure more sources than in the past (e.g. transient sources). The sensitivity of radio astronomy telescopes is in fact proportional to the square of bandwidth. However, an increase in sensitivity is accompanied by a higher vulnerability to interference.

Theoretically, radio observatories would require greater bandwidths in order to capitalise on the availability of powerful back-end systems. In reality, however, it is possible that the frequencies that can be used are limited by other spectrum users transmitting at the frequencies that the observatories are trying to detect, thus causing interference. Therefore, this trend may result in demand for more geographical exclusion zones, where transmitting at some frequencies is not allowed when close to a radio observatory.

5.11.2 Very long baseline interferometry

Technology trend	Short term	Medium term	Long term
Very long baseline interferometry (VLBI)	=	=	=

Figure 5.67: Assessment of the impact of VLBI on spectrum usage demand [Source: Analysys Mason, 2013]

Relatively recent advances in signal processing techniques in the back-end mean that very large arrays of small radio telescopes can be designed to act as one very large detector. According to the Committee on Radio Astronomy Frequencies (CRAF), "*VLBI is a radio astronomical technique based upon the recording of the amplified cosmic radio emissions in raw form (although down-converted in frequency and then sampled), along with precise timing and reference signals*."[41]

The most advanced of these new VLBI detectors is the Square Kilometre Array, which is to be built across Australia and South Africa between 2016 and 2024. While these new detectors may not necessarily use more spectrum than previous radio telescopes, they might require geographical radio exclusion zones in more areas, to reduce interference.

5.12 Satellite systems (Satellite)

The civilian satellite category is broad, covering all satellite applications that use spectrum (with the exception of defence systems). It includes TV broadcasting, fixed satellite services (FSS) and mobile satellite services (MSS), and covers a range of spectrum bands.

Currently, considering bands from 400 MHz to 6 GHz, satellite systems use mainly the following frequency bands:

- 400–401 MHz
- 406–406 MHz
- 1164–1215 MHz
- 1525–1610 MHz
- 1614–1661 MHz
- 1980–201 MHz
- 2025–2110 MHz
- 2170–2290 MHz
- 2484–2500 MHz
- 3600–4200 MHz
- 5000–5030 MHz
- 5875–6425 MHz.

Many of these bands are not exclusively for satellite usage and are often shared with other services.

Overall, as shown in Figure 5.68, our impact assessment on future spectrum usage demand for satellite will mainly depend on the success of S-band services and DAB, as well as the continuing popularity of the L-band.

41 CRAF Handbook for Radio Astronomy, 2012.

Figure 5.68: Summary of satellite technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Multi-input element low noise block (M-LNB)	=	=	=
L-band MSS	+	+	+
Ku-band FSS	=	=	=
Galileo navigation system	=/+	=/+	+
Satellite L-band DAB	–	–	–
High-speed satellite broadband	=	=	=
Mobile satellite services	=	=	=
OVERALL ASSESSMENT	**=**	**=**	**=**

5.12.1 M-LNB

Technology trend	Short term	Medium term	Long term
Multi-input element low noise block (M-LNB)	=	=	=

Figure 5.69: Assessment of the impact of M-LNB on spectrum usage demand [Source: Analysys Mason, 2013]

M-LNB is a technology which can be used at FSS earth stations to improve service performance. The system works by reducing interference caused by other satellites that are adjacent to the one in use, to a much greater extent than conventional low noise blocks. As a result, M-LNB can be used on C-band FSS to increase throughput, and to reduce dish size.

However, the technology is highly unlikely to have an impact on spectrum usage demand; rather, it is aimed at improving the performance and convenience of C-band systems.

5.12.2 L-band MSS

Technology trend	Short term	Medium term	Long term
L-band MSS	+	+	+

Figure 5.70: Assessment of the impact of L-band MSS on spectrum usage demand [Source: Analysys Mason, 2013]

Some satellite operators are still investing heavily in L-band technology, for the provision of MSS. For example, Inmarsat will soon be launching Alphasat, which will provide MSS in the extended L-band, largely aimed at supporting satellite phone users.

With the number of satellites and services that use L-band spectrum on the rise, it seems reasonable that this trend will cause an increase in spectrum usage demand; this is likely to be met by existing designations, however.

5.12.3 Ku-band FSS

Technology trend	Short term	Medium term	Long term
Ku-band FSS	=	=	=

Figure 5.71: Assessment of the impact of Ku-band FSS on spectrum usage demand [Source: Analysys Mason, 2013]

Although out of scope of this study (as it is above 6 GHz), the Ku-band is largely used for FSS and is highly congested. There is therefore a possibility that lower bands such as the C-band might become more attractive to some applications that would otherwise use the Ku-band, if no additional Ku-band spectrum is found or made available (e.g. new satellites in existing orbital locations, or new orbital locations).

Overall, we understand that studies to examine the substitution of some Ku-band services with other bands are at a very preliminary stage, and so it seems unlikely that this trend will have an impact on spectrum usage demand between 400 MHz and 6 GHz in the next ten years.

5.12.4 Galileo navigation system

Technology trend	Short term	Medium term	Long term
Galileo navigation system	=/+	=/+	+

Figure 5.72: Assessment of the impact of the Galileo navigation system on spectrum usage demand [Source: Analysys Mason, 2013]

The European satellite navigation constellation (Galileo) will use ~120 MHz of spectrum in the L-band, which has already been designated. To date, four satellites have been launched. As the project deployment continues, the usage of this designation will increase, although this increase in usage is only likely to happen in the long term.

5.12.5 Satellite L-band DAB

Technology trend	Short term	Medium term	Long term
Satellite L-band DAB	–	–	–

Figure 5.73: Assessment of the impact of satellite L-band DAB on spectrum usage demand [Source: Analysys Mason, 2013]

There is uncertainty about the future of satellite L-band DAB;[42] if the service is unsuccessful, the designated spectrum could be handed back. Indeed, the CEPT is currently investigating this band (1479.5–1492 MHz) for other uses, with one possible application being downlink for mobile services.[43] Therefore, the abandonment of L-band satellite DAB could result in a reduction in spectrum usage demand from the satellite sector.

42 Satellite digital audio broadcasting (satellite DAB) is a digital radio service, similar to terrestrial DAB, but transmitted from satellites.

43 See http://www3.ebu.ch/cms/en/sites/ebu/contents/knowledge/technology/news/201210/cept-paves-the-way-for-mobile-se.html

5.12.6 High-speed satellite broadband

Technology trend	Short term	Medium term	Long term
High-speed satellite broadband	=	=	=

Figure 5.74: Assessment of the impact of high-speed satellite broadband on spectrum usage demand [Source: Analysys Mason, 2013]

The newest satellite broadband applications use the Ku-band, or, more likely, the Ka-band, which is well above 6 GHz. Therefore, there will be no impact on the bands being considered by this study.

5.12.7 Mobile satellite services

Technology trend	Short term	Medium term	Long term
Mobile satellite services	=	=	=

Figure 5.75: Summary of impact of mobile satellite services [Source: Analysys Mason, 2013]

The spectrum that is used for mobile satellite services aims to deliver all types of communications – video, radio, voice and interactive services – to mobile devices.

Solaris and Inmarsat were awarded S-band MSS spectrum in 2009.[44] Since then, we understand that Inmarsat has put its S-band satellite project (EuropaSat) 'on hold', while Solaris has actively engaged with vendors, operators and Member States to establish a clear roadmap for the successful launch of these new services. Additionally, Solaris has experienced issues with its payload not being able to provide the capacity that was initially envisaged. We have no clear evidence of the success of these services to date, and it is now more than three years since the spectrum was first awarded. Although this is not an unreasonable time for the launch of new services (DAB and DVB-H attempts have run for much longer), it might be considered a lengthy period when compared to other much more immediate uses of spectrum (such as DTT or traditional mobile services).

European spectrum assignments run until 2027,[45] and satellite operators claim that they are still investigating a number of potential applications for the use of S-band MSS spectrum. Moreover, the European Space Agency (ESA) is still funding studies into MSS using the S-band.

However, despite these efforts, there are still some industry concerns about the likely success of these new services in the S-band in the long term. These may be similar to the concerns raised regarding future demand for satellite-DAB and DVB-H. If these concerns prove well founded, there could be a reduction in the amount of spectrum designated to MSS. Given the current licence commitments and the fact that this study focuses on the next ten years, we believe that any such potential reduction will have to be considered/assessed again in the future.

44 See http://space.skyrocket.de/doc_sdat/europasat.htm

45 See http://europa.eu/rapid/press-release_MEMO-09-237_en.htm#PR_metaPressRelease_bottom

5.13 Short-range devices (SRDs)

Short-range devices are essentially low-power radio communications systems which provide either uni- or bi-directional communication. SRD is a generic term for a wide range of low-power radio equipment that supports numerous wireless applications such as Wi-Fi hotspots (at 2.4GHz), Bluetooth inter-device connections (e.g. hands-free car kits), machine-to-machine (M2M) communications, ITS and road safety applications, health and well-being devices and Internet of Things applications.

Overall, as shown in Figure 5.76, our impact assessment on future spectrum usage demand for SRDs will mainly depend on the technologies continuing to mature, which will make SRDs more widespread and thus increase their spectrum needs.

Figure 5.76: Summary of SRD technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
Technology developments	–	–	–
Harmonisation of modulation techniques	=	=	=
Medical applications	=/+	=/+	=/+
Radio-frequency identification (RFIDs)	+	+	+
Geo-location databases	–	–	–
OVERALL ASSESSMENT	**=**	**=**	**=**

5.13.1 Technological developments

Technology trend	Short term	Medium term	Long term
Technology developments	–	–	–

Figure 5.77: Assessment of the impact of technology developments on spectrum usage demand [Source: Analysys Mason, 2013]

The following technological developments are particularly relevant to this trend:

- **Cognitive radio**, designed to recognise its location and the systems operating around it, and then transmit in accordance with a spectrum plan that is pre-stored in its memory. The underlying idea of cognitive radio is that a radio can vary the frequency that it uses for communication depending on local conditions, such as which frequencies are the most suitable or least congested. This technology trend also goes hand in hand with spectrum sharing and white spaces (see Section 5.3.3). Cognitive radio is also used in other categories such as PPDR, ITS and mobile.

- **Duty cycle limits**, which limit the duration of each transmit burst and the rate of repetition.

- **Spread spectrum transmission** (SST), which involves ‘spreading’ a modulated signal of a given bandwidth over a substantially wider RF bandwidth.

- **Listen before talk** (LBT), which requires the SRD receiver to check for the presence of other users on the frequency before proceeding to transmit.
- **Dynamic frequency selection** (DFS), which, instead of postponing transmission from a device, enables it to identify which of the available frequencies are already in use and select a frequency that is vacant.
- **Ultra wideband** (UWB), which is a more extreme form of DFS where the required signal is spread over a bandwidth of several GHz.

These technologies could allow SRDs to operate in some bands that are currently reserved exclusively for licensed applications. This would incentivise the adoption of SRDs, which in turn would mean more efficient use of the available spectrum, leading to a decrease in spectrum usage demand from a technology trend point of view. However, these developments would require advances in the regulation of white-space technology, and we note that there has been very limited progress in this area outside the UK and the USA.

Overall, most of the technology developments are designed to optimise existing use of spectrum, and so from a technological perspective it can be expected to lead to a decrease in spectrum usage demand.

5.13.2 Harmonisation of modulation techniques

Technology trend	Short term	Medium term	Long term
Harmonisation of modulation techniques	=	=	=

Figure 5.78: Assessment of the impact of harmonisation of modulation techniques on spectrum usage demand [Source: Analysys Mason, 2013]

This is a further development of software-defined radio. The aim of harmonising the modulation of technologies is to reduce equipment manufacturing costs and increase the take-up of the related devices. As such, regulatory developments could increase the availability and popularity of these devices:

- Prior to the EN 300 220 specification, the US and European bodies took very different regulatory approaches on SRDs. The USA adopted a frequency-hopping approach, while Europe applied duty-cycle limits in each of the sub-bands.
- European EN 300 220 regulations have extended the frequency bands available for SRDs to allow for frequency-hopping spread-spectrum (FHSS) or direct-sequence spread-spectrum (DSSS). This makes the Media Access Control layer (MAC) implementations more similar to those designed for the USA, but some fine-tuning will still be required.

Therefore, as the degree of harmonisation increases and the production costs of these devices fall, the popularity of devices based on software-defined radio is likely to grow. However, this would appear to be an impact related to consumers and communities, with the impact from the technology trend alone being limited.

5.13.3 Medical applications

Technology trend	Short term	Medium term	Long term
Medical applications	=/+	=/+	=/+

Figure 5.79: Assessment of the impact of medical applications on spectrum usage demand [Source: Analysys Mason, 2013]

Medical body area network (MBAN) systems are intended to provide a wireless connection for multiple body sensors that are used for patient monitoring within hospitals, as well as for patient diagnosis and treatment. Since the connection between sensors in an MBAN system is wireless, this means that devices can be used in ambulances or in the home, as well as in hospitals.

Currently the majority of spectrum employed for MBANs in Europe is between 401 MHz and 406 MHz; however, several other portions of bands have been proposed in the 600 MHz, 1400 MHz, 2300 MHz and 2400 MHz bands. As with many other applications, there would be large benefits for the EU in terms of technology development and production if spectrum bands were to be harmonised with US designations; however, this trend may be limited by the spectrum bands that are suitable for medical applications.

Overall, there is some likelihood of growth in the range and number of devices in this area over the next few years, leading to a possible increase in spectrum usage demand, particularly if devices are harmonised with non-EU states.

5.13.4 Radio-frequency identification

Technology trend	Short term	Medium term	Long term
Radio-frequency identification (RFID)	+	+	+

Figure 5.80: Assessment of the impact of RFID on spectrum usage demand [Source: Analysys Mason, 2013]

RFID uses radio frequencies to transfer data from a tag carrying identification data to a reader that can interpret the data. The tag consists of an RFID chip attached to an antenna. Tags may be active (battery-powered) or passive (drawing power from the electromagnetic field created by the reader). The applications of RFID tags are numerous, but everyday examples include the Oyster cards used for travel on London's public transport network, contactless credit and debit cards (which are becoming increasingly common in the UK), security tags attached to clothing and other items in shops to deter theft, and microchips implanted in pets to help reunite them with their owners if they are lost.

The European Communications Office forecasts substantial growth of RFID devices over the next ten years (from 0.7 billion tags in 2009 to 124 billion tags in 2019). Furthermore, ETSI identified a need for further spectrum for RFIDs and non-specific SRDs:

- the main frequency range for RFIDs is currently 903–929 MHz
- 870–876 MHz has been identified for non-specific SRDs
- 915–921 MHz has been identified as a future band for high-power devices such as RFIDs.

It therefore appears that there will be growth in this sector, and as with other large-scale SRDs it is important that any additional spectrum is internationally harmonised, particularly across the EU and the USA. This trend is therefore likely to lead to an increase in spectrum usage demand as the number of RFID devices continues to grow.

5.13.5 Geo-location databases[46]

Technology trend	Short term	Medium term	Long term
Geo-location databases	–	–	–

Figure 5.81: Assessment of the impact of geo-location databases on spectrum usage demand [Source: Analysys Mason, 2013]

This is a technology whereby a 'master' SRD first consults a list of databases provided online. It then selects its preferred database from this list and sends it the parameters describing the SRD's location and device attributes. The database then returns details of the frequencies and power levels that the SRD is allowed to use. This is a similar technology to spectrum sharing and white spaces (see Section 5.3.3); in the UK, this is the model chosen by the regulator, Ofcom, for white-space devices.

It therefore seems reasonable to assume that the degree to which these devices become mainstream will depend on the regulatory regimes employed, and therefore the impact on spectrum usage demand may vary across Member States. However, in general, geo-location databases are designed to optimise existing use of spectrum, and so from a technological perspective it can be expected to lead to a decrease in spectrum usage demand.

5.14 WLAN/RLAN (WLAN)

This category mainly covers Wi-Fi technologies, and so primarily focuses on fixed wireless broadband rather than cellular services (discussed in Section 5.3 earlier). As mentioned in Section 5.3.4, Wi-Fi has become a ubiquitous technology, and the majority of data from mobile devices is now carried over Wi-Fi networks, both private and public. Moreover, the trend is to increase this level of offloading as data consumption continues to grow in the coming years.

Overall, as shown in Figure 5.82, our impact assessment on future spectrum usage demand for WLAN will mainly depend on three technology trends:

- new Wi-Fi standards
- Wi-Fi roaming (offloading)
- universal hotspots.

[46] We note that this trend is also relevant for a number of other categories, such as mobile, ITS, PPDR and wideband.

Figure 5.82: Summary of WLAN technology trends and assessment of their relative impact on spectrum usage demand [Source: Analysys Mason, 2013]

Technology trend	Impact assessment (short term)	Impact assessment (medium term)	Impact assessment (long term)
New Wi-Fi standards	+	+	+
Wi-Fi roaming (offloading)	+	+	+
Universal hotspots	+	+	+
OVERALL ASSESSMENT	**+**	**+**	**+**

5.14.1 New Wi-Fi standards

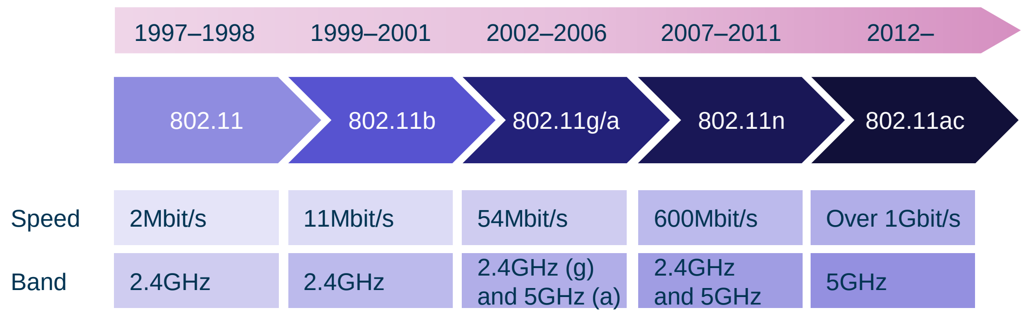
Technology trend	Short term	Medium term	Long term
New Wi-Fi standards	+	+	+

Figure 5.83: Assessment of the impact of new Wi-Fi standards on spectrum usage demand [Source: Analysys Mason, 2013]

Currently, Wi-Fi can operate on the 2.4 GHz and 5 GHz bands, although 2.4 GHz is the more-commonly employed band. As such, this band has become congested, and there are 14 overlapping channels[47] that occupy the space between 2.4 GHz and 2.4385GHz, each of a width of 22 MHz and spaced every 5 MHz; of these, only three channels will not overlap. As such, it is likely that increasing use will be made of the 5 GHz Wi-Fi band in future, with more devices supporting this mode of operation. This is likely to result in Wi-Fi offering higher data rates (albeit over shorter distances), but could also result in a congestion of the 5GHz band, as has happened at 2.4 GHz.

Figure 5.84 shows the evolution of Wi-Fi standards over the last 16 years.

Figure 5.84: Evolution of Wi-Fi standards [Source: Analysys Mason Research, 2012]



802.11b was the first widely adopted Wi-Fi standard, which became popular in Europe in the early 2000s. This standard was superseded by 802.11a (which was exclusive to the 5 GHz band, and thus not compatible with existing 802.11b equipment) and 802.11g (2.4 GHz only), both of which offered higher throughput rates, and it was 802.11g, which became mainstream across Europe. The latest iteration of Wi-Fi that has been widely adopted is 802.11n, which enables higher throughput

47 The 14th channel is not used in Europe.

in both the 2.4 GHz and 5 GHz bands, by integrating single-user MIMO (SU-MIMO).[48] The 802.11n standard is also compatible with older equipment.

The next generation of Wi-Fi standard is 802.11ac, which is defined for 5 GHz devices only. It introduces the following techniques.

- 256-QAM, up from 64-QAM in directly preceding standards, which quadruples the physical-layer data rate
- the possibility of channel bonding to create channels of up to 80 MHz and 160 MHz; this involves the concatenation of channels to create a virtual, larger, wireless pipe, which results in an increase in achieved throughput over the air interface
- multi-user MIMO (MU-MIMO), which enables access points to communicate with several client devices simultaneously.

As developments in Wi-Fi are generally geared towards increasing data throughput speeds rather than reducing spectrum use, it is likely that any gains in spectral efficiency will translate into higher performance standards, using the same amount of bandwidth. As the 2.4 GHz band becomes increasingly congested, more Wi-Fi devices will become capable of using the 5 GHz band, and so Wi-Fi's spectrum usage will increase over the next ten years.

5.14.2 Wi-Fi roaming (offloading)

Technology trend	Short term	Medium term	Long term
Wi-Fi roaming (offloading)	+	+	+

Figure 5.85: Assessment of the impact of Wi-Fi roaming on spectrum usage demand [Source: Analysys Mason, 2013]

Another area of WLAN where technology trends are occurring is within the active-offload sector – this is where operators attempt to offload data from their cellular networks onto strategically placed Wi-Fi networks in cafés, shopping malls, etc. Although this has advantages for the operator (in the form of reduced traffic on its macro-cellular network) and the consumer (with potentially faster data rates that 2G or 3G), it also has its challenges, for example the difficulty of achieving seamless Wi-Fi roaming.

A number of standards are emerging which will improve the experience for Wi-Fi hotspot users, such as the certified Passpoint programme, which aims to make using Wi-Fi a similar experience to use of the automated and secure cellular network. Both the Wi-Fi Alliance (WFA) and the Wireless Broadband Alliance (WBA) are promoting the Passpoint programme, which combines their individual carrier Wi-Fi enhancement projects – Hotspot 2.0 and Next Generation Hotspot, respectively.

48 SU-MIMO is the basic version of MIMO (which is described in more detail in Annex B).

Passpoint involves the user's device searching for nearby networks that are broadcasting Wi-Fi at the 802.11u standard. Passpoint then determines whether the subscription is supported on the network, and if it is, uses information on the user's SIM to register the device on the network, without the user having to input any details. This approach therefore improves the user experience of Wi-Fi hotspots by automating the negotiations for support and roaming agreements between the device and the network.

It appears likely that further technology trends will appear in this area in the near future, with the first range of Passpoint-compliant devices, access points and software clients being announced in June 2012 from a number of manufacturers (including BelAir Networks, Broadcom, Cisco Systems, Intel, Marvell, MediaTek, Qualcomm and Ruckus Wireless).

Passpoint has three main elements to ensure effective network selection, authentication and security, as shown below in Figure 5.86.

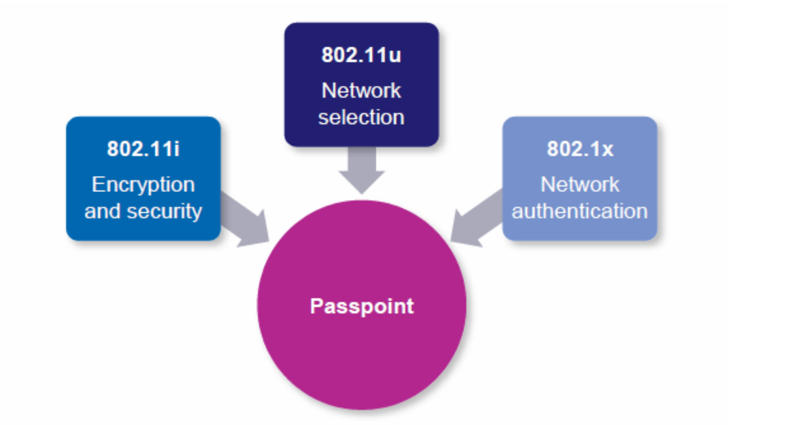


Figure 5.86: The three elements of the Passpoint framework [Source: Analysys Mason, 2012]

- 802.11u access points emit a beacon to signal their presence. The signal can also provide additional information about the network, such as the premises where it is located, the aggregator, and the supported roaming partners. Support for 802.11u on handsets is likely to become common in two years' time.
- 802.11i is the underlying protocol in Passpoint that controls security, addressing weaknesses in previous wired equivalent privacy (WEP) encryption technologies.
- 802.1x is a security standard which enables automatic authentication with the Wi-Fi network, using information on the subscriber's SIM.

Overall, these advances will further enable Wi-Fi offloading, transferring the spectrum demand from cellular data services to WLAN services.

5.14.3 Universal hotspots

Technology trend	Short term	Medium term	Long term
Universal hotspots	+	+	+

Figure 5.87: Assessment of the impact of universal hotspots on spectrum usage demand [Source: Analysys Mason, 2013]

Universal hotspots represent a trend that has emerged across Europe, whereby the home Wi-Fi routers of broadband customers are used to broadcast public hotspots.

The technology is not new; BT has been supplying its broadband customers in the UK with FON-enabled wireless routers for the last few years, allowing them to share their networks in return for having free access to other customers' FON networks. BT claims that its network is the largest Wi-Fi network in the world, with millions of members, and therefore hotspots. In 2010, Dutch cable operator Ziggo announced a similar scheme,[49] and has been available to Belgacom customers in Belgium for some time. FON, whose technology powers BT's system, aims to create a 'crowdsourced Wi-Fi' community. Its routers create two Wi-Fi zones – a private one for the home user, where the vast majority of the available backhaul capacity is focused, and a secondary public spot, which other FON members (or indeed paying customers) are able to access. BT claims that this set-up does not result in any noticeable reduction of speed for the home user.

Overall, the adoption of this technology trend largely relies on having a large broadband operator supplying suitably equipped routers to its customers; as such, the impact of this trend is likely to vary significantly by Member State. According to FON,[50] the main Member States of relevance are Belgium, France, the Netherlands, Poland, Portugal and the UK.

Although future technology advances in this area are unlikely to be significant, the apparent growing popularity of these dual-zone routers is likely to put further pressure on the increasingly congested licence-exempt Wi-Fi bands. We therefore expect a positive increase in spectrum demand in the next ten years.

49 See http://cablecongress.wordpress.com/2012/10/24/ziggo-turns-customers-wi-fi-into-public-network/

50 See http://maps.fon.com/en

6 Analysis of consumer- and community-driven demand

This section analyses consumer and community related demand trends by application category, and assesses the potential impact on demand for future spectrum usage that the consumer and community trends alone are likely to have over the next ten years. For most categories, an increase in demand for future spectrum usage is due to the adoption of new services and devices, which in turn generate traffic that needs to be catered for.

Figure 6.1 shows a summary table which displays the complete list of consumer and community trends, and the overall impact assessment on demand for future spectrum each for each category, as a result of these associated consumer and community trends.

Figure 6.1: Overview of consumer and community trends by category and overall assessments of impact on demand for future spectrum usage [Source: Analysys Mason, 2013]

Category	Consumer and community trends	Impact on demand for future spectrum usage		
		ST	*MT*	*LT*
AMCRN	Growth in air-passenger traffic	=	=/+	+
	Growth in air-freight traffic			
	Growth in sea-freight traffic			
	In-flight high-speed broadband and live-TV services			
	Implementation of Single European Sky ATM Research (SESAR), 'the spectrum / technology' dimension of SES			
	Mandates to implement technology advances			
	Integration of RPAS into the civilian airspace			
Broadcast	Growing linear TV consumption	+	+/++	+/++
	Growth in the number of TV channels			
	Adoption of DTT			
	Take-up of DAB			
	Adoption of HDTV / UHDTV / 3DTV			
	Adoption of over-the-top (OTT) and impact on DTT			
	Number of MUXs			
	Digital TV switchover in Central and Eastern Europe (CEE)			
	Technology migration path			
Mobile	Strong adoption of more sophisticated devices	+	+/++	+/++
	Adoption of data-intensive mobile applications			
	Increase of mobile data speeds			
	Adoption of M2M			
	Growth in Wi-Fi offload			
	Deployment of femtocells			
	Launch of LTE/LTE-Advanced			
	Number of mobile network operators			
	Spectrum sharing and white spaces			

Category	Consumer and community trends	Impact on demand for future spectrum usage		
		ST	*MT*	*LT*
Defence	Growth in activity in the Defence sector Growth in information exchanged (enhanced connectivity) Increase in unmanned aeronautical systems Potential compression benefits from new technologies Potential of freeing spectrum designated to Defence Increase in satellite use with civil and governmental assets Potential to switch to commercial services / operators	=	+	++
Fixed	Microwave-to-fibre substitution Deployment of new mobile base stations Demand for higher-frequency links Take-up of services that require low latency	=/--	-	--
ITS	Development and take-up of ITS applications: • traffic and freight management • integration vehicle-infrastructure • new ITS applications	=	+	++
MET	Global Observing Systems (GOS) World Meteorological Organization Integrated Global Observing System (WIGOS) Harmonisation	=	=	=
PMR	General PMR/PAMR Smart grid and smart metering ECTS and GSM-R replacement	=/+	+	+
PMSE	Type and number of events Type of equipment and growth Increase in the amount of equipment per event Adoption of HD and 3D cameras	+	+	+/++
PPDR	Increasing demand for data-rich applications Growth in PPDR communications Use of commercial services Adoption of new technologies	=	+	++
Science	Usage demand	=	=	=
Satellite	L-band (~1–2 GHz) S-band (~2–3 GHz) C-band (~3–7 GHz)	=/+	+	+
SRDs	Take-up of automotive SRDs Growth in the use of SRDs for medical apps Growth of RFID devices Growth of alarms Growth of home and building automation Harmonisation of modulation techniques New requirements in the automotive industry	+	+	+

Category	Consumer and community trends	Impact on demand for future spectrum usage		
		ST	*MT*	*LT*
WLAN	Continued growth in Wi-Fi network reach and increased user adoption	+	+	+
	Growth in the number of hotspots			
	Growth in rural fixed wireless access			
	Release of spectrum designated for WiMAX use			

6.1 Aeronautical, maritime and civil radiolocation and navigation systems (AMCRN)

This section examines the main drivers of spectrum demand for AMCRN systems and assesses their impact on spectrum usage demand in the short, medium and long term. Overall, our analysis indicates that future demand for spectrum for AMCRN services will be driven primarily by the following four factors:

- the actual demand for, and commercial success of, high-speed broadband and in-flight live-TV services
- implementation of the Single European Sky (SES) initiative
- mandates to implement new technologies
- demand for commercial remotely piloted aircraft systems (RPAS) flight services.

Figure 6.2: Summary of the main drivers of spectrum demand for AMCRN systems and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

	Impact on spectrum usage demand (short term)	Impact on spectrum usage demand (medium term)	Impact on spectrum usage demand (long term)
Growth in air-passenger traffic	=	=/+	=/+
Growth in air-freight traffic	=	=/+	=/+
Growth in sea-freight traffic	=	=	=/+
In-flight high-speed broadband and live-TV services	=	+	++
Implementation of Single European Sky ATM Research (SESAR), 'the spectrum / technology' dimension of SES	=	=/+	=/+
Mandates to implement technology advances	=	=/+	=/+
Integration of RPAS into the civilian airspace	=/+	+	++
OVERALL ASSESSMENT	**=**	**=/+**	**+**

We discuss each of these factors in turn.[51]

Growth in air-passenger traffic

Technology trend	Short term	Medium term	Long term
Growth in-air passenger traffic	=	=/+	=/+

Figure 6.3: Impact of the growth in air-passenger traffic on spectrum usage demand [Source: Analysys Mason, 2013]

The economic downturn has led to a reduction in the number of flights in recent years. Notwithstanding this, forecasts agree that the European airline industry will recover in the medium to long term. As an example, below we present a set of forecasts from relevant industry stakeholders:

- Airbus forecasts a compound annual growth rate (CAGR) of 4.3% in revenue passenger kilometre (RPK) traffic in Europe between 2012 and 2021[52]
- Boeing predicts a 4.1% CAGR in RPK traffic in Europe between 2011 and 2031[53]
- Japan Aircraft Development Corporation estimates a 4.4% CAGR in RPK traffic in Europe between 2011 and 2030[54]
- Air Transport Action Group (ATAG) forecasts a 5% CAGR in international traffic in Europe between 2010 and 2015.[55]

Similarly, Figure 6.4 shows the forecasts of instrumental flight rules (IFR) movements in Europe published by the European Organisation for the Safety of Air Navigation (EUROCONTROL) in 2010[56] and 2012.[57] According to EUROCONTROL, the air industry will not reach the number of IFR flights in Europe that existed before the economic slowdown until 2015. As Figure 6.4 shows, the forecasts from 2010 are more aggressive than the updated forecasts from September 2012, which expect a slower recovery from the economic recession than previously predicted.

51 Wireless avionics intra-communications (WAIC) have not been included in this analysis as this technology appears to be more relevant beyond 2022.

52 Airbus (2012), *Global Market Forecasts 2012–2031.* Available at: http://www.airbus.com/company/market/forecast/

53 Boeing (2012), *Current Market Outlook 2012– 2031.* Available at: http://www.boeing.com/commercial/cmo/

54 Japan Aircraft Development Corporation (2012), *Worldwide Market Forecast For Commercial Air Transport 2012–2031*. Available at: http://www.jadc.or.jp/wmf12.pdf

55 ATAG (2012), *Aviation Benefits Beyond Borders*. Available at http://www.aviationbenefitsbeyondborders.org/download-abbb-report

56 EUROCONTROL (2010), *EUROCONTROL Long-Term Forecast – Flight movements 2010-2030*. Available at https://www.eurocontrol.int/sites/default/files/content/documents/official-documents/forecasts/long-term-forecast-2010-2030.pdf. We note that Figure 6.4 only includes the 'regulated growth scenario', which, according to EUROCONTROL, is the 'most likely' scenario.

57 EUROCONTROL (2012), *EUROCONTROL Seven-Year Forecast. September 2012. Flight Movements 2012–2018*. Available at http://www.eurocontrol.int/sites/default/files/content/documents/official-documents/forecasts/seven-year-flight-forecast-2012-2018-sep12.pdf. We note that Figure 6.4 only includes the base case scenario.

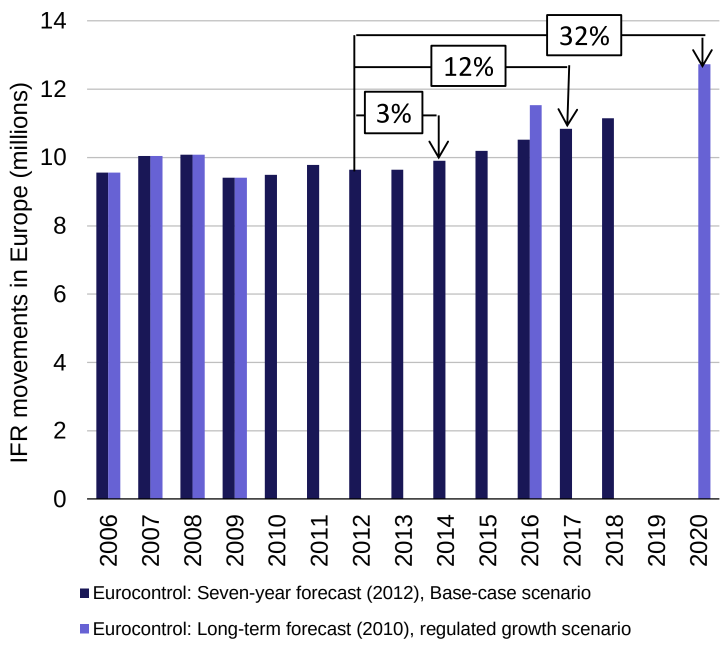


Figure 6.4: Forecast of IFR movements in Europe [Source: EUROCONTROL, 2012 and 2010]

Overall, and taking into account that the economic downturn is still hindering the expected recovery in the aviation industry, we do not expect that the growth in air-passenger traffic will have a material impact on spectrum usage demand in the medium to long term.

Growth in air-freight traffic

Technology trend	Short term	Medium term	Long term
Growth in air-freight traffic	=	=/+	=/+

Figure 6.5: Impact of the growth in air-freight traffic on spectrum usage demand [Source: Analysys Mason, 2013]

In line with the expected evolution of air-passenger traffic, air-freight traffic is forecast to grow in Europe in coming years:

- Airbus forecasts a 4.8% CAGR in freight tonne kilometre (FTK) traffic in Europe between 2012 and 2021,[58] and expects that the freight fleet in Europe and in the Commonwealth of Independent States (CIS) will grow from 275 in 2012 to 500 in 2031[59]
- Boeing predicts a 4.6% CAGR in FTK traffic in Europe between 2011 and 2031.[60]

Figure 6.6 shows the forecasts from Airbus with regards to the growth in global air traffic until 2022. According to Airbus, air-freight traffic will begin to recover in 2013, and grow rapidly thereafter.

58 Airbus (2012), *Global Market Forecasts 2012–2031.* Available at http://www.airbus.com/company/market/forecast/

59 Airbus (2012), *Global Market Forecasts 2012–2031.* Available at http://www.airbus.com/company/market/forecast/

60 Boeing (2012), *Current Market Outlook 2012–2031.* Available at http://www.boeing.com/commercial/cmo/

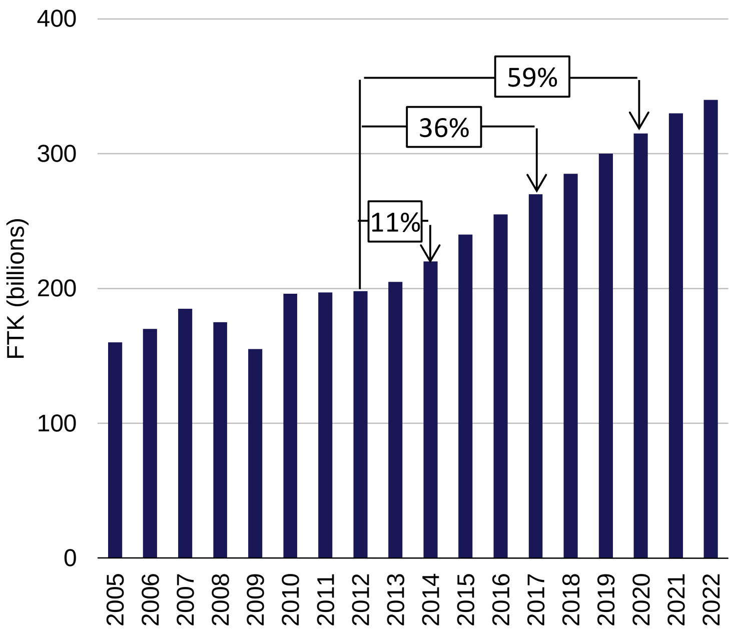


Figure 6.6: Forecast of global air-freight traffic [Source: Boeing, 2012]

Our own assessment indicates that the expected growth in air-freight traffic in Europe may have an impact on spectrum usage demand in the medium to long term.

Growth in sea-freight traffic

Technology trend	Short term	Medium term	Long term
Growth in sea-freight traffic	=	=	=/+

Figure 6.7: Impact of the growth in sea-freight traffic on spectrum usage demand [Source: Analysys Mason, 2013]

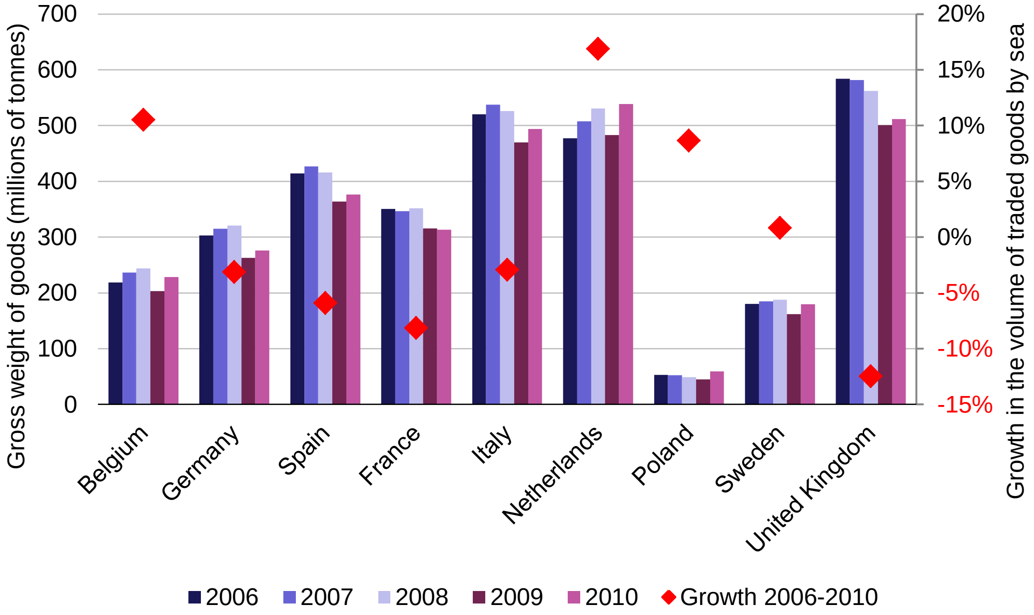
We have analysed this factor from two different angles:

- growth in the gross weight of goods handled in European ports
- growth in European imports and exports of goods.

► *Growth in the gross weight of goods handled in European ports*

Figure 6.8 shows the evolution in the volume of goods handled in nine European ports in recent years. As can be seen from the graphic in Figure 6.8, the volume of traded goods has only grown considerably in three out of the nine ports analysed. Indeed, in countries such as the UK, the volume of traded goods by sea fell by 12% between 2006 and 2010 – although a study from MDS Transmodal suggests that the total tonnage of goods handled in UK ports will recover during 2012–2020, growing by 17%.

Figure 6.8: Volume of goods handled in each of the main European ports, 2006–2010 [Source: Eurostat]



► *Growth in European imports and exports of goods*

The United Nations Conference on Trade and Development (UNCTAD) states that about 80% of the total volume of imports and exports of goods is carried by sea.[61] This figure is higher in countries such as the UK, where, according to the UK Department for Transport, the volume of imports and exports that arrives by sea reaches a 95% of the total volume of traded goods.[62]

According to the World Economic Outlook Database from the International Monetary Fund (IMF),[63] the volume of exports and imports of goods in Europe is recovering and will grow in coming years (see Figure 6.9 and Figure 6.10). We expect that the expected growth in the volume of exports and imports of goods within the EU would lead to growth in sea-freight traffic, which may in turn lead to increased spectrum usage.

61 UNCTAD (2012), *Review of Maritime Transport 2012.* Available at http://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=380

62 UK Department for Transport (2012), *Sustaining a thriving maritime sector*. Available at https://www.gov.uk/government/policies/sustaining-a-thriving-maritime-sector

63 IMF (2012), *World Economic Outlook Database*. Available at http://www.imf.org/external/pubs/ft/weo/2012/01/weodata/index.aspx

Figure 6.9: Volume of exports of goods [Source: IMF, 2013]

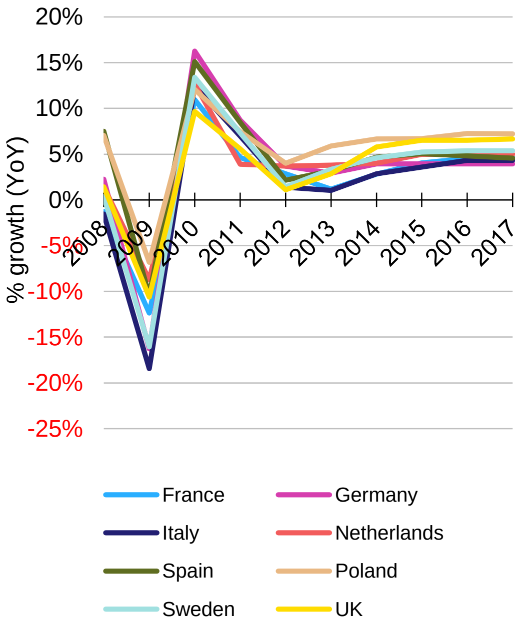
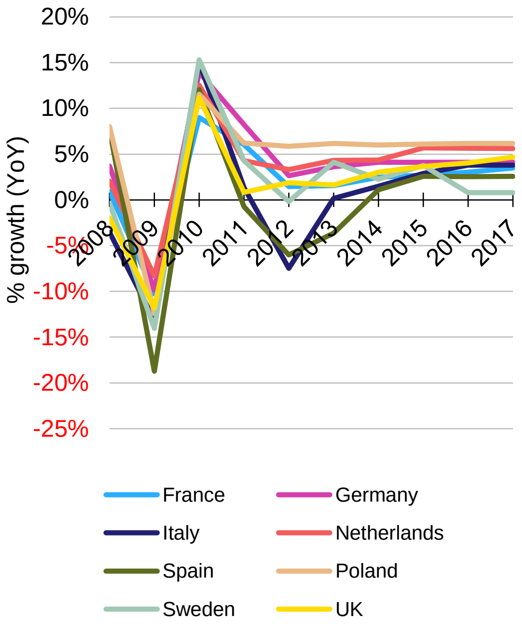


Figure 6.10: Volume of imports of goods [Source: IMF, 2013]



► *Overall impact*

Even though sea-freight traffic is forecast to grow in coming years, the decrease in the traded volume of goods following the economic downturn seems to suggest that this driver will only have an impact on spectrum usage demand in the long term.

It is important to note that the growth in sea-freight traffic does not seem to have a strong impact on spectrum requirements as sea space is relatively uncongested, except for certain areas, such as the English Channel. Safety and security seem to be the key factors driving spectrum usage demand in the maritime sector.

In-flight high-speed broadband and live-TV services[64]

Technology trend	Short term	Medium term	Long term
In-flight high-speed broadband and live TV services	=	+	++

Figure 6.11: Impact of high-speed broadband and in-flight live-TV services on spectrum usage demand [Source: Analysys Mason, 2013]

64 Note: This is a customer broadband application not related to safety, and so will not use the aeronautical safety spectrum.

Demand for high-speed broadband, live-TV and cellular connectivity services is expected to grow rapidly over the next few years. For example, IMS Research forecasts that the number of aircraft equipped with Wi-Fi and cellular connectivity will grow by 386% between 2012 and 2021 (see Figure 6.12).

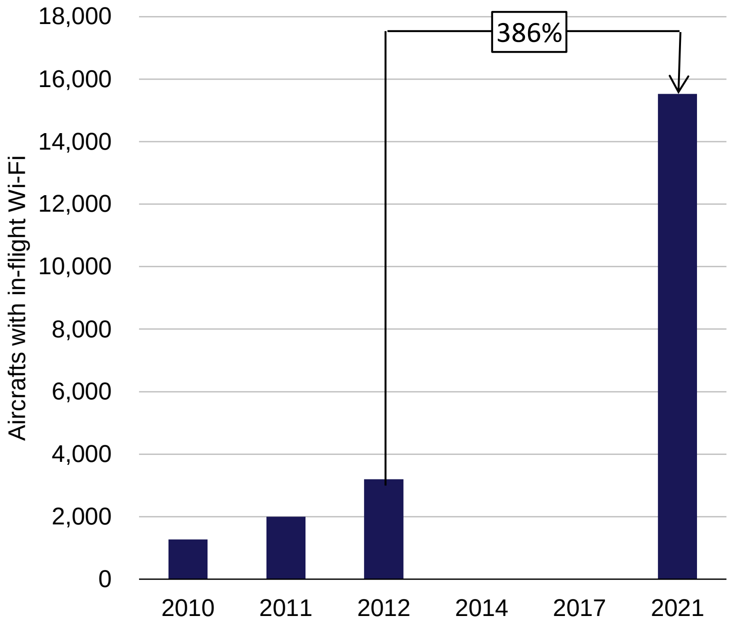


Figure 6.12: Aircraft equipped with Wi-Fi and cellular connectivity [Source: IMS Research, 2012]

Similarly, a survey conducted by a big European airline concluded that most European passengers would favour the idea of having access to broadband services in-flight. According to this study, 74% of the passengers surveyed would be interested in having access to broadband services in short-haul flights within Europe. For long-haul flights, this figure reaches 91% of passengers.

In-flight high-speed broadband, live-TV and cellular connectivity services will drive the demand to install air-to-ground (A2G) and satellite-based solutions in aircraft. The only technology available on transoceanic routes is satellite, while stakeholders are still arguing about whether A2G or satellite solutions will be the technology of choice on continental flights.

According to IMS Research, A2G technology will lead the market until 2015. From 2016 onwards, it expects that the Ku-band will become the most popular technology to provide in-flight connectivity, with a 36% market share of aircraft. Finally, IMS Research expects that the Ka-band will become the market leader in 2021, with up to 6000 installations.

However, the conclusions from that study have been seriously criticised by aviation industry stakeholders across Europe, noting that the IMS Research study does not take into account the new A2G deployments in Europe, China and India. They argue that if these new deployments were considered, A2G systems would lead the market even beyond 2015. Lower costs, lower latency and quick installation time are among the benefits listed by stakeholders to state that this technology will be the preferred choice for continental flights.

A consortium formed by Deutsche Telekom, Airbus and Alcatel–Lucent has already carried out trials on several European flights using A2G systems. The consortium used 2×10 MHz of spectrum on a trial frequency in the 2.6GHz band, achieving peak data rates of approximately 30Mbit/s. However, A2G systems are not expected to be launched in Europe before 2015. Another successful test flight was carried out by Lufthansa Systems using the 5.8 GHz band.

It is expected that A2G will result in an increase in spectrum usage due to its requirement for a dedicated and harmonised designation. For example, the CEPT has already determined that A2G services will require spectrum, with overall demand likely to be either 2×10 MHz frequency division duplexing (FDD) or 20MHz time division duplexing (TDD).[65] By contrast, the American A2G system (i.e. GoGo) only uses 2×3 MHz in the 800 MHz band. It will be extended soon to 2 x 4 MHz.

It is important to note that many organisations within the aeronautical industry (such as the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA)) have claimed that A2G is strictly speaking not an aeronautical application as it concerns commercial telecom services for passengers. As a result, both ICAO and IATA have requested to remove the 960–1164 MHz, 1350–1375 MHz, 2700–2900 MHz, 4200–4400 MHz, 5091–5150 MHz and 5150–5170 MHz bands from consideration for A2G services.

We have included in-flight high-speed broadband and line TV services under AMCRN however this is a commercial service, which are not related to aircraft safety.

Implementation of SESAR, 'the spectrum / technology' dimension of SES

Technology trend	Short term	Medium term	Long term
SESAR	=	=/+	=/+

Figure 6.13: Impact of the implementation of SESAR on spectrum usage demand [Source: Analysys Mason, 2013]

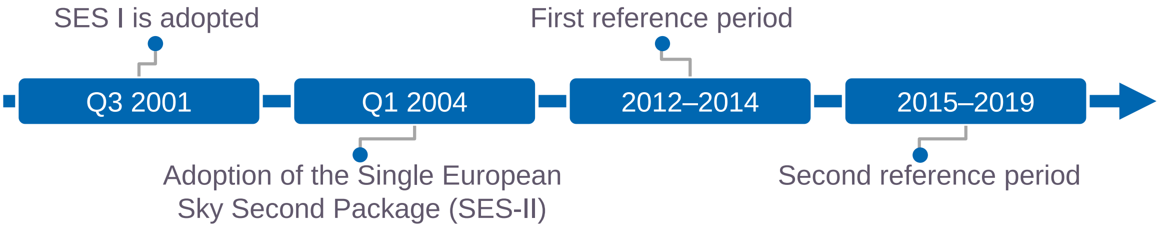
► *The SES initiative*

The SES initiative, which is being implemented by EUROCONTROL, aims to streamline and harmonise the air-traffic control system across Europe. SES is also focused on efficiency, splitting Europe into functional airspace blocks, rather than having airspace ending at country borders.

Figure 6.14 shows the main milestones defined in the SES timeline.

65 Note: A2G is a customer broadband application not related to safety, and so will not use the aeronautical safety spectrum.

Figure 6.14: Main milestones in the SES timeline [Source: Analysys Mason, 2013]



However, a key deadline was missed in December 2012,[66] which has drawn criticism on whether or not the Member States will succeed in achieving the milestones defined in the SES roadmap.

In order to avoid a delay in the implementation of the SES, the EC has warned that infringement procedures may be launched against those Member States which fail to meet the deadlines. In addition, the EC will present a new package of legislative measures in Spring 2013 to accelerate the ongoing reforms and ensure the full delivery of the SES.

► *SESAR*

The SESAR programme is the technological dimension of SES. It aims to build a single European system to manage air traffic over the next 30 years. SESAR consists of different programmes, such as the Single European Sky Iris programme, which is a research initiative to improve the air traffic management through the use of satellite-based navigation systems.

SESAR will be built on the Global Navigation Satellite System (GNSS). This will lead to a transition from the current ground-based navigation system to a satellite-based navigation system, which may result in:

- freeing up spectrum designated to conventional navigation applications (such as Non-directional Beacon/Automatic Direction Finder (NDB/ADF)) in lower-frequency bands; however, this factor would not have an impact on our study as these systems operate in bands using frequencies lower than 400MHz, and it is not expected that this spectrum will be freed before 2022[67]
- an increase in satellite spectrum usage.

GNSS constellations are designed not only to work independently, but also to become interoperable. This will improve accuracy, integrity and availability of the service, providing an incentive for the airline industry to implement these satellite-based navigation systems. However, some of the GNSS constellations are not expected to become fully operational before 2020 at the earliest, which could delay the implementation of these satellite-based systems on board aircraft.

66 December 2012 was the deadline to implement nine fully operational Functional Airspace Blocks (FABs) in Europe. However, many Member States were not fully compliant with all the requirements defined in the programme.

67 Vulnerability of GNSS to interference might require the retention of other legacy ground-based navigation systems in order to safeguard from possible GNSS failures. Consequently, it is not expected that the spectrum used by other ground-based navigation systems will be released before 2022.

In addition, it is expected that SESAR will drive demand for terrestrial safety data communication systems. These systems are usually provided using the VHF band; however, the relatively high level of congestion in this band has led to consider other alternatives. The L-band (with the L-band Digital Aeronautical Communication System (LDACS)) and to a lesser extent the C-band (Aeronautical Mobile Airport Communications System (AeroMACS)) have been identified as the next best bands to support these terrestrial data communication links. It is important to note that the proposed bands for these links (i.e. 960–1164 MHz and 5091–5150 MHz) have usually been used by the aeronautical safety systems, so this might not lead to new designations of spectrum bands.

► *Overall impact*

It is expected that the SES initiative will require additional satellite spectrum frequencies in the medium to long term. However, failure to meet the milestones defined in the SES timeline might delay the implementation of the SES, and, consequently, the needs for spectrum.

Mandates to implement technology advances

Technology trend	Short term	Medium term	Long term
Technology advances	=	=/+	=/+

Figure 6.15: Impact of the take-up of new technologies on spectrum usage demand [Source: Analysys Mason, 2013]

Here we discuss the public policies that will be required to implement technology advances in the maritime and aeronautical sector in the coming years, and assess the expected impact of such policies on spectrum usage demand.

► *Technology advances in the maritime sector*[68]

eNavigation

eNavigation is a system which aims to collect, integrate and analyse all the ship's data (e.g. AIS, GNSS) at one common place. It is expected that eNavigation will provide, among others, the following benefits:

- reduce complexity in vessels' operations
- reduce costs
- improve safety
- provide more accurate information.

The International Maritime Organization (IMO) group on eNavigation will release its Strategic Implementation Plan before the end of 2014. It is expected that this plan will define the mandatory dates by which various classes of vessels and shore entities will be required to implement this new system. However, the roll-out of eNavigation is unlikely to occur in the short to medium term.

68 New high-speed data links between vessels using standards such as RTCM SC-123 have not been included in our analysis as they operate in the VHF band.

Automatic Identification System (AIS)

AIS is a tracking system used to localise and identify vessels.

In 2004, the IMO's International Convention for the Safety of Life at Sea (SOLAS) required that, no later than July 2008, all passenger ships, cargo ships of 500 or more tons and international voyaging ships with gross tonnage over 300 tons are fitted with this system.

The Council Regulation (EC) No 1224/2009 extended this requirement to the following ships:[69]

- since May 2012, to all EU fishing vessels of 24 metres length or more
- since May 2013, to all EU fishing vessels of 18 metres length or more
- since May 2014, to all EU fishing vessels of 15 metres length or more.

AIS operates in the VHF band, so the implementation of these devices should not have an impact on spectrum usage demand in the frequency bands being analysed.

► *Technology advances in the aeronautical sector*

Automatic Dependent Surveillance – Broadcast (ADS-B)

ADS-B is a radiolocation technology used in the aviation industry. Unlike primary radars, ADS-B consists of a global navigation satellite system (GNSS) receiver in each aircraft, which then broadcasts its position back to the supervisory authority. The signal can be captured on the ground (ADS-B Out) or on board other aircraft (ADS-B In). There are more than 1300 aircraft certified to use ADS-B in non-radar airspace.

The International Civil Aviation Organization (ICAO) expects that the implementation of these systems will bring the following benefits to the aviation industry:[70]

- enhancement of safety
- flight efficiency
- reduction of the minimal separation between aircraft
- cost reduction
- increase in capacity.

In the USA, the Federal Aviation Administration (FAA) is currently deploying the required infrastructure, and expects 700 ground stations to be in operation by 2014. The 978 MHz and 1090 MHz frequencies are used for ADS-B in the USA; however, global harmonisation is a likely requirement for its widespread adoption.

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69 The Council of the European Union (2009), *COUNCIL REGULATION (EC) No 1224/2009 of 20 November 2009*. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:343:0001:0050:EN:PDF

70 ICAO (2007), *Global Air Navigation Plan, Doc 9750 AN/963.*

In Europe, the Surveillance Performance and Interoperability Implementing Rule (SPI IR) mandates that aircraft, with a take-off mass exceeding 5700kg or with a maximum cruising speed greater than 250knots must be 'ADS-B Out' compliant. Mandate dates are January 2015 for new aircraft and December 2017 for aircraft built before 2015.[71]

It seems highly unlikely, however, that primary radar systems will be switched off or significantly scaled down as a result of the introduction of ADS-B. For example, from a safety perspective, ADS-B requires a working unit on each aircraft, whereas primary radar systems do not require the aircraft to actively respond to the broadcast signal.

Mode S Elementary (ELS) and Mode S Enhanced (EHS)

ELS systems are an evolution of secondary radar technology. Unlike secondary radars, which interrogate all aircraft within the range of the ground station, Mode S systems are able to actively select which aircraft to interrogate, resulting in better quality and integrity of the data received, which could result in improvements in safety, capacity and efficiency in European airspace.

ELS systems offer basic functionality, reporting information such as the aircraft identity and flight status. EHS systems offer more advanced reporting, such as roll angle and ground speed.

Public policies in Europe will have an important impact on the integration of these systems into the aircraft within European airspace:

- Since March 2009, state aircraft in Europe flying in Mode S must be ELS-compliant.
- All fixed-wing aircraft with a take-off mass exceeding 5700kg or with a maximum cruising speed greater than 250knots must be SSR Mode S-compliant in Europe. Mandate dates are January 2015 for new aircraft and December 2017 for aircraft built before 2015.[72]

Wide-area multilateration (WAM)

WAM is another radar development where a number of ground receivers pick up signals transmitted from an aircraft.[73] WAM works at 1090 MHz, similarly to ADS-B.

In Europe, EUROCONTROL's CASCADE project focuses on the implementation of surveillance applications (i.e. ADS-B, WAM). There are plans underway to implement WAM and ADS-B in Europe and in the rest of the world over the next years.

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71 European Commission (2011), *Commission Implementing Regulation (EU) No 1207/2011 of 22 November 2011 laying down requirements for the performance and the interoperability of surveillance for the single European sky*. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:305:0035:01:EN:HTML

72 *Ibid*.

73 National Aerospace Laboratory (2004), *Wide Area Multilateration Report on EATMP TRS 131/04.* Available at http://www.eurocontrol.int/sites/default/files/content/documents/nm/surveillance/surveilllance-report-wide-area-multilateration-200508.pdf

The introduction of these new technologies into the European airspace is expected to provide benefits not only in terms of safety, cost reduction and efficiency, but also in terms of reduced spectrum usage. However, the impact of implementing these technologies will depend on whether or not the spectrum designated to the legacy systems is released (i.e. there might be an increase in spectrum usage demand in the short to medium term until the legacy systems are switched off).

Integration of RPAS into the civilian airspace

	Short term	Medium term	Long term
RPAS	=/+	+	++

Figure 6.16: Impact of the integration of RPAS into the civilian airspace on spectrum usage demand [Source: Analysys Mason, 2013]

Remotely piloted aircraft systems (RPAS) refer to all type of aircraft which are remotely controlled. There are two aspects of RPAS that require spectrum:

- control and non-payload communications
- payload communications.

We discuss each of these in turn.

Spectrum requirements for control and non-payload communications

If unmanned aircraft are going to operate in non-segregated airspace where passenger aircraft operate, they must be integrated safely, with dedicated systems that use aeronautical 'safety' spectrum (agenda item 1.5 for the World Radiocommunication Conference in 2015 deals with this). According to the ITU-R M.2171 report,[74] the maximum amount of spectrum required for RPAS is:

- 34 MHz for a terrestrial line-of-sight (LoS) link
- 56MHz for satellite beyond line-of-sight (BLoS) links.

The 5030–5091 MHz band was deemed to be the most suitable for RPAS safety applications at the World Radiocommunication Conference in 2012, while 960–1164 MHz seems to be the most suitable band for terrestrial links.

EUROCONTROL has also conducted a study to determine the spectrum requirements for the Command, Control and Communication link (C3) to support RPAS. In that study, EUROCONTROL assessed the spectrum requirements for the C3 link using the following technologies:

- terrestrial-based C3 network based on L-DACS1 (L-band digital aeronautical communication system) technology
- terrestrial-based C3 network based on Inmarsat SBB (spot beam) technology.

74 ITU (2009), *Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace.* Available at http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2171-2009-PDF-E.pdf

The table below summarises the estimated spectrum requirements for the two technologies in 2020.[75]

Figure 6.17: Spectrum requirements for the C3 link to support RPAS in 2020 [Source: EUROCONTROL, 2010]

Video quality	Terrestrial-based C3 network based on L-DACS1 technology	Terrestrial-based C3 network based on Inmarsat SBB (spot beam) technology
Low-rate video	31.5MHz	38.4MHz
High-rate video	1160.3MHz	1518.0MHz

Spectrum requirements for Sense and Avoid (S&A) systems

S&A systems will require sending data of the terrain and weather from/to RPAS. This information will be used to monitor flight progress, to alert pilots of existing objects that need to be avoided, and to allow pilots to take manual control of the RPAS if required.[76]

Spectrum requirements for payload communications

Many RPAS applications will require a significant amount of bandwidth for the payload, for example for video links from the air to the ground. It is therefore possible that RPAS will increase demand for L-band MSS spectrum and C-band feeder links.[77]

Clearly, this is not specifically an aeronautical safety band, but it will have an impact on the civilian satellite sector (see Section 6.12), and possibly the demand for fixed links (see Section 6.5). It is expected that the spectrum requirements for this type of service will exceed the amount of bandwidth required for control and non-payload communications.

The number of companies operating RPAS is forecast to grow rapidly. For example, the ITU projects that the number of civil RPAS units will grow by 1250% between 2012 and 2022, as shown below in Figure 6.18.[78]

75 EUROCONTROL (2010), *UAS C3 Channel Saturation Study Final Report.*

76 *Ibid*.

77 It is expected that payload communications for RPAS applications will mostly use satellite spectrum in the Ku- and Ka-bands, which are out of the scope of the present study.

78 ITU (2009), *Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace.* Available at http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2171-2009-PDF-E.pdf

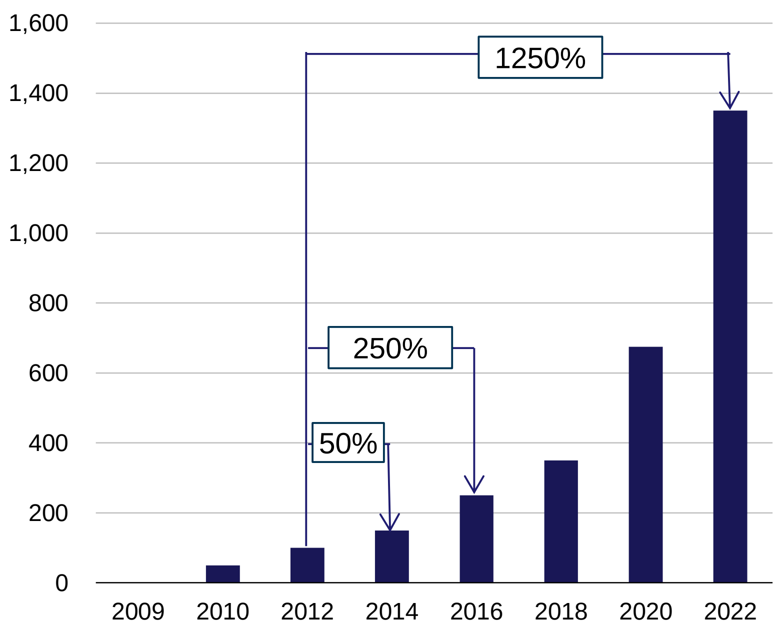


Figure 6.18: Forecast of the number of commercial RPAS in service worldwide [Source: ITU, 2009]

Similarly, a study carried out by Frost & Sullivan on behalf of the EC forecasts that the number of RPAS units in Europe will grow rapidly from 2013 onwards (see Figure 6.19).[79] This forecast seems to present a mistake as the total number of RPAS units goes up and down between 2017 and 2020.

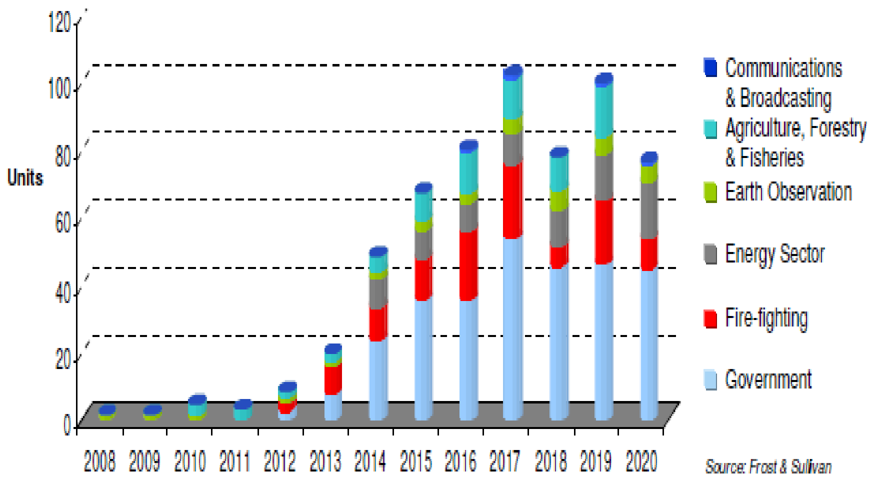


Figure 6.19: Forecast of European civil and commercial unmanned aerial vehicles (UAV) [Source: Frost & Sullivan, 2007]

79 Frost & Sullivan (2007), *ENTR/2007/065 Study analysing the current activities in the field of UAV.* Available at http://ec.europa.eu/enterprise/policies/security/files/uav_study_element_2_en.pdf

6.2 Terrestrial broadcasting (Broadcasting)

TV services can be provided over a plethora of platforms. Traditionally, TV has been delivered in Europe via terrestrial, satellite and cable networks, where available. Terrestrial broadcasting remains a widely used TV platform among a large proportion of consumers in the EU-27.

In the last ten years there has been a progressive digitalisation of TV networks (cable, satellite and, more recently, terrestrial). In addition, a combination of the development of IPTV (a TV service delivered through a managed broadband connection), the increasing take-up of video services (streaming, linear and video-on-demand (VoD)) provided over the Internet, and the proliferation of devices on which video services can be enjoyed (standard TVs, connected TVs, tablets, laptops, notebooks and smartphones) are changing the way viewers watch TV.

Whilst some improvements (such as the adoption of more effective compression algorithms) have led to greater broadcast efficiency, increasing demand for higher-quality and therefore more bandwidth-hungry services could increase spectrum usage, if delivered over terrestrial networks.

Overall, our impact assessment on future demand for spectrum for broadcast mainly depends on:

- the digitalisation of terrestrial TV (analogue switch-off/digital switchover) in Central and Eastern Europe
- the number of TV channels that each market will be able to sustain
- the rise in use of new TV quality standards by existing channels (HDTV, ultra-high definition television (UHDTV) and 3DTV) and the extent to which their use is offset by improvements in compression techniques (MPEG-4 and high-efficiency video coding (HEVC)).

Figure 6.20: Summary of spectrum demand drivers for broadcast and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

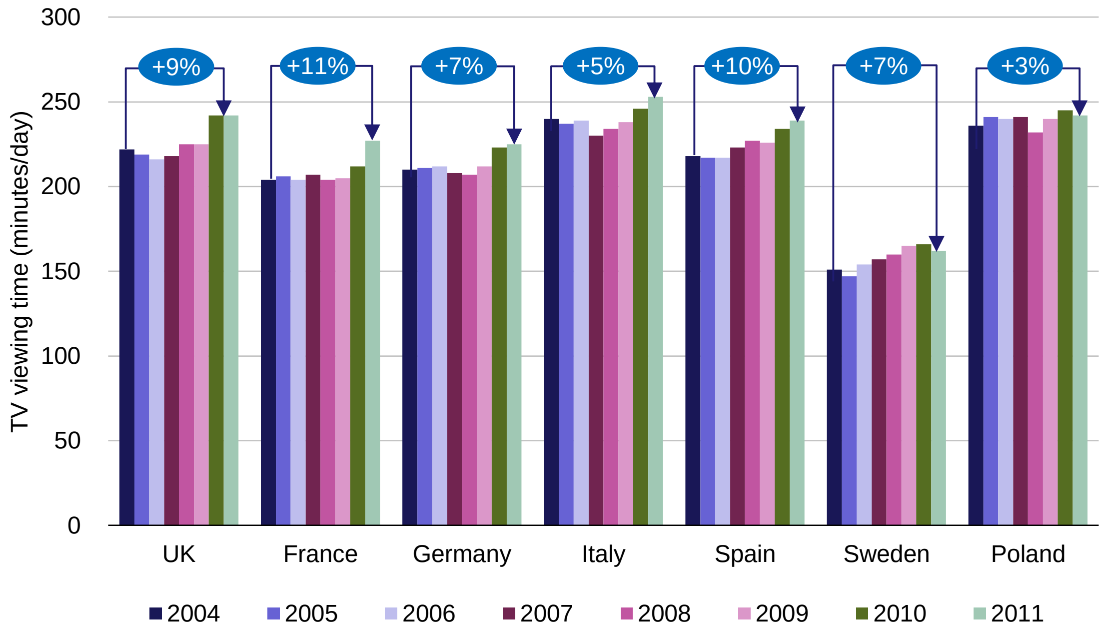
Broadcast	Short term	Medium term	Long term
Growing linear TV consumption	=	=	=
Growth in the number of TV channels	+	=	=
Adoption of DTT	=	=	=
Take-up of DAB	=	= / +	= / +
Adoption of HDTV / UHDTV / 3DTV	+	++	++
Adoption of over-the-top (OTT) and impact on DTT	=	=	=
Number of MUXs	+	+	+
Digital TV switchover in Central and Eastern Europe (CEE)	=/+	=	=
Technology migration path	+	++	++
OVERALL ASSESSMENT	**+**	**+/++**	**+/++**

We therefore expect to see a net increase in spectrum usage demand for terrestrial broadcasting, based on the assumption that all existing TV channels move to higher-quality and higher-compression standards.

Growing linear TV consumption

Despite the increase in Internet penetration among European households over the last ten years, TV remains a major source of entertainment. Indeed, as shown in Figure 6.21, TV viewing time increased between 3% and 11% in the period 2004–2011 in selected markets. This shows that demand for TV services, regardless of the platform on which they are provisioned (terrestrial, satellite, cable, IPTV or video over broadband), grew in the observed period.

Figure 6.21: Time spent viewing TV in selected European countries [Source: Ofcom Communications Market Report, European Audiovisual Observatory]



Traditionally, linear TV has been the default for viewers when deciding what to watch, with broadcasters scheduling TV programmes with no direct involvement from viewers. Technological developments, the deployment of new network infrastructures and content proliferation have been leading viewers to directly select their preferred schedule (e.g. non-linear TV services such as VoD).

Non-linear TV consumption is expected to grow by 174% during 2012–2020. Nevertheless, it is anticipated to account for a small share of daily TV viewing per person.

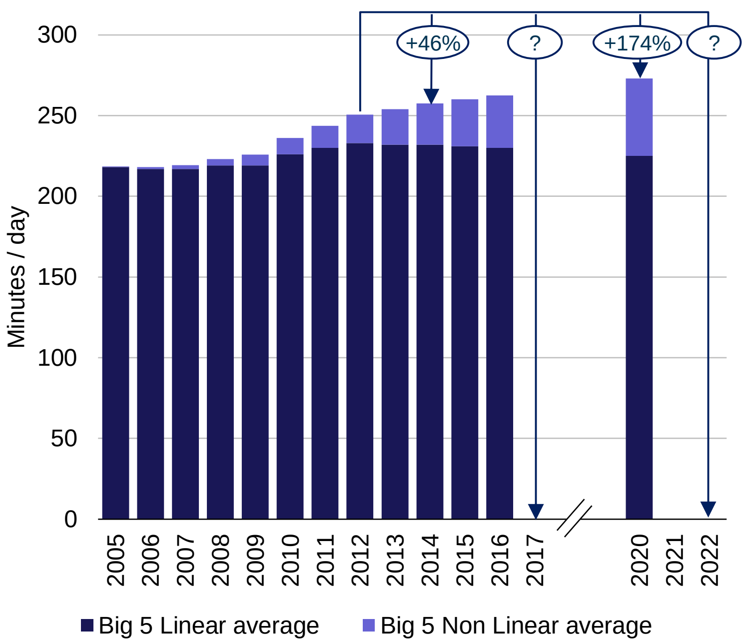


Figure 6.22: Linear vs. non-linear daily TV viewing in Europe [Source: EBU based on IHS – ScreenDigest]

TV viewing time has been increasing year-on-year and this trend is set to continue in coming years. Even if technology supports access to on-demand video content and via online streaming, linear, over-the-air and free TV will remain the leading medium for most Europeans. TV viewing has an impact on spectrum demand only indirectly. The continuous increase in linear TV viewing minimises the threat from connected TV, which indicates that demand for linear TV and DTT is likely to be sustained in future.

Technology trend	Short term	Medium term	Long term
Viewing services	=	=	=

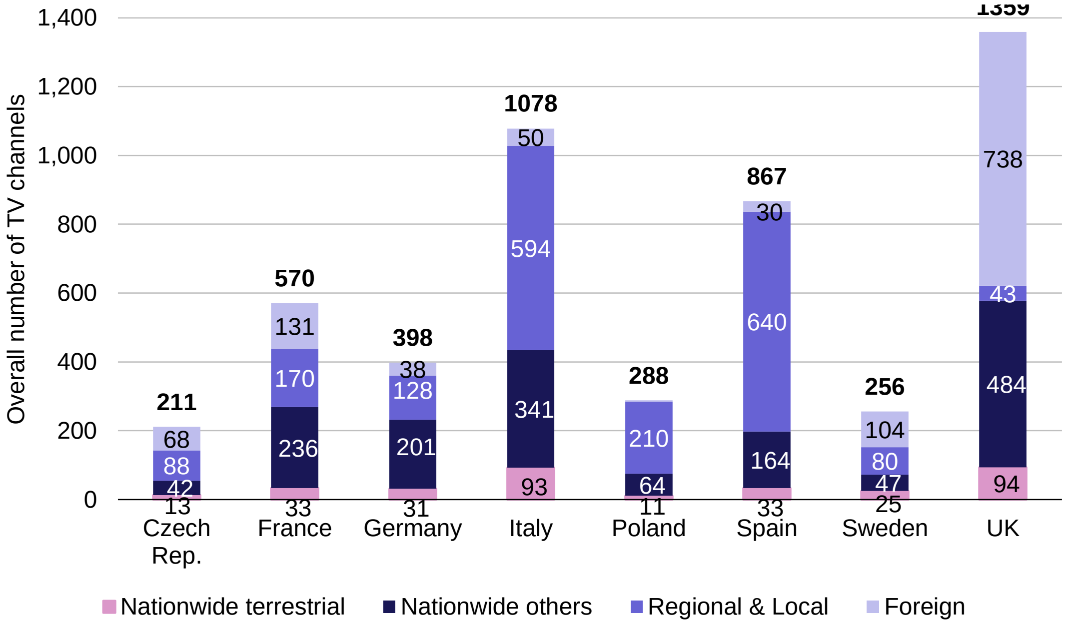
Figure 6.23: Impact of viewing services on spectrum usage demand

Growth in the number of TV channels

The total number of TV channels broadcast in the studied countries increased by 42% (i.e., 12% per annum) between 2008 and 2011, driven by the digital switchover (DSO).

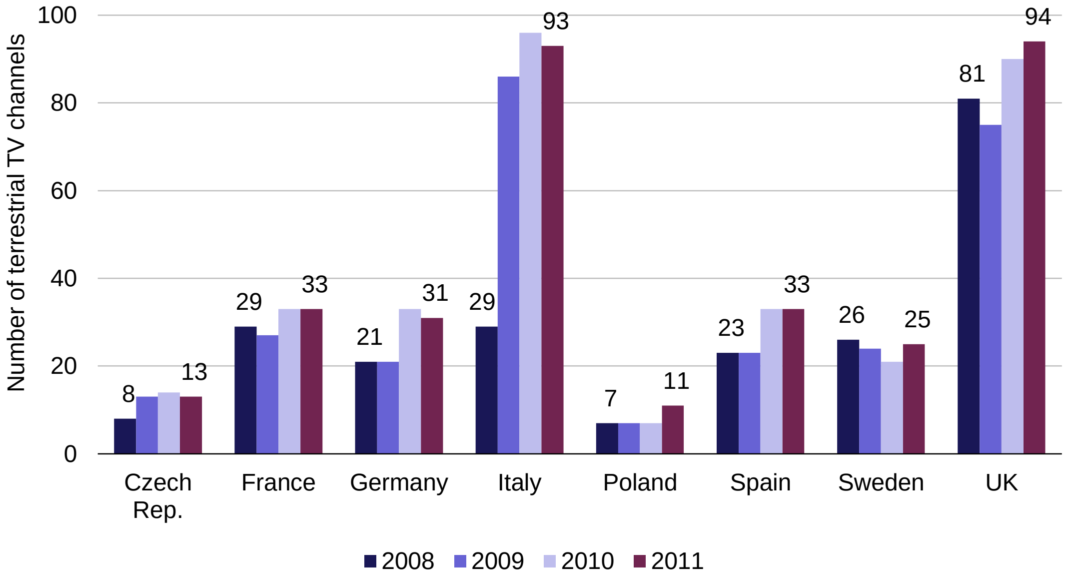
Over 100 channels are available on terrestrial TV in both the UK and Italy, followed by Spain, France and Germany. The number of nationwide TV channels is also highest in the UK and Italy, while the number of regional and local TV channels is particularly high in Spain and Italy. In the UK, more than 700 foreign channels are broadcast via satellite.

Figure 6.24: Number of TV channels available in the studied countries (2011) [Source: European Audiovisual Observatory]



The total number of nationwide terrestrial TV channels available in the studied countries grew by 49% (i.e. 14% per annum) between 2008 and 2011.

Figure 6.25: Evolution of nationwide terrestrial TV channels [Source: European Audiovisual Observatory]



The average number of national TV channels is also growing across the EU-27.

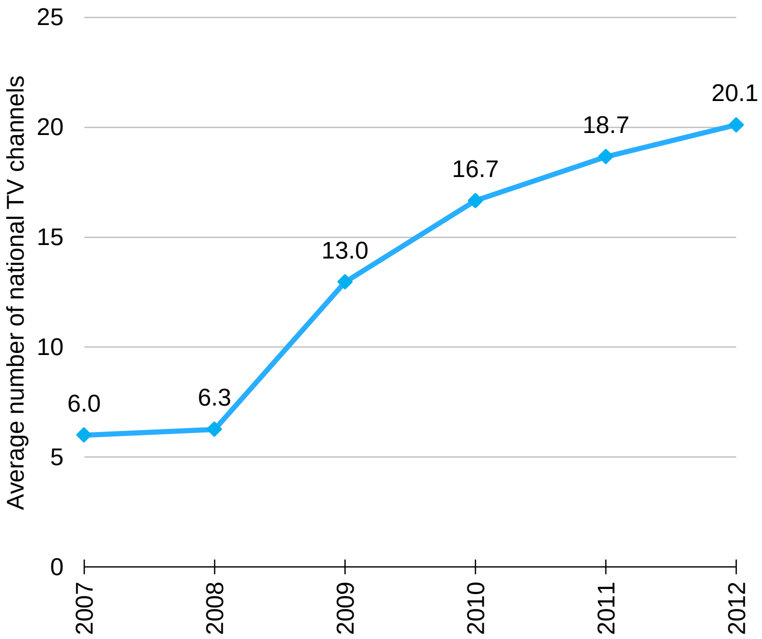


Figure 6.26: Average number of national TV channels in the EU-27 [Source: Euromonitor]

The increasing number of terrestrial TV channels as a result of the migration to DTT is expected to increase the demand for spectrum for terrestrial broadcasting in Europe in the future. Such a trend, however, is projected to stabilise in the long term, once the DSO is completed, unless new multiplexes become available. Notwithstanding this, ultimately this will be subject to policy decisions at Member State level.

Technology trend	Short term	Medium term	Long term
Number of TV channels	+	=	=

Figure 6.27: Impact of the number of TV channels on spectrum usage demand [Source: Analysys Mason, 2013]

Adoption of DTT

Varying levels of consumer adoption of different platforms directly affect broadcasters' interest for different broadcast media. Demand for DTT spectrum is determined by the number of TV channels being broadcast, which in turn depends on platform attractiveness, measured in terms of household take-up. This is particularly important for free-to-air (FTA) DTT based on advertising; however, other models exist in which pay DTT can be sustainable with penetration levels of less than 10% of TV households.

DTT, by supporting an ever increasing number of channels, has made terrestrial transmissions more and more attractive from the point of view of broadcasters. Terrestrial channels only require a standard TV set to be received, which increases the attractiveness of DTT for TV viewers. In particular, DTT take-up is higher in countries where no other physical infrastructure (i.e. cable or fast broadband) can support a capillary distribution of the TV signal (e.g. this is the case in Italy).

Within Member States, the number of multi-TV households is high and many secondary TV sets are likely to use terrestrial networks for broadcasting reception. Therefore, terrestrial penetration statistics may be adjusted downward if they do not include secondary reception.

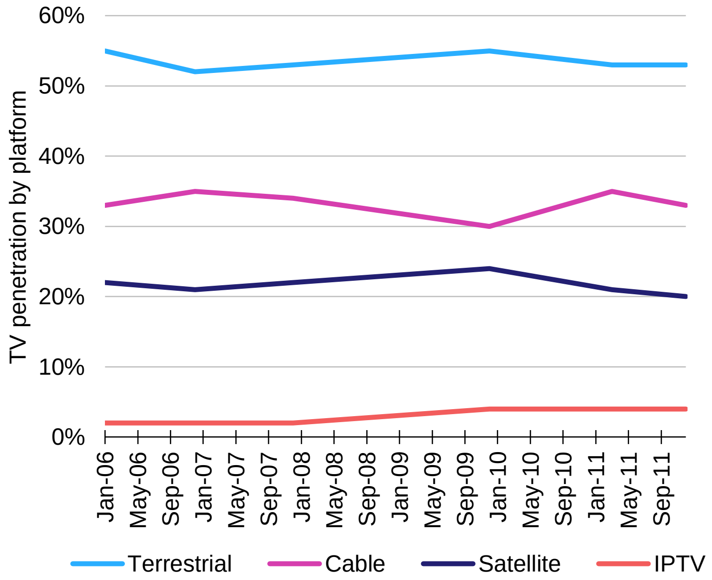


Figure 6.28: Penetration of TV platforms in the EU [Source: RSPG]

In 2011, the proportion of DTT households was highest in Spain and Italy, followed by the UK, but the situation varies widely across countries (in Germany, for example, DTT is only available to 10% of TV households).

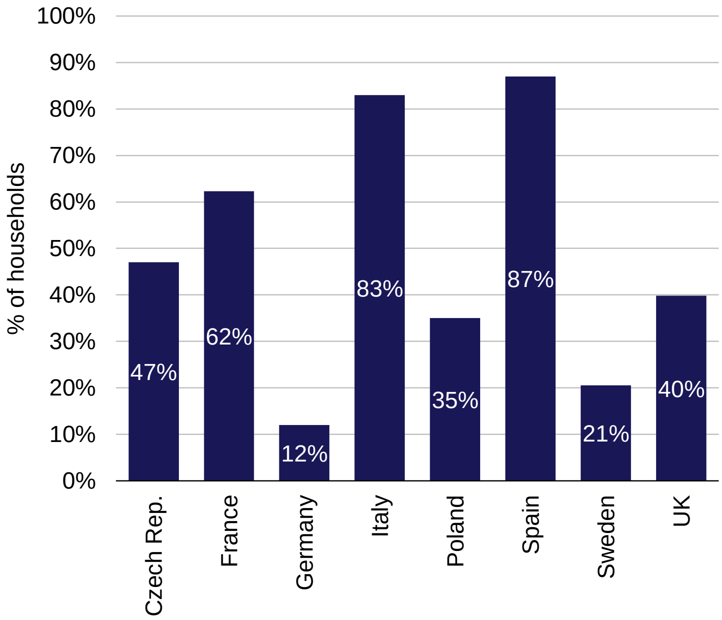


Figure 4.16: Households using terrestrial broadcasting for primary reception [Source: Ofcom, 2012]

The continued existence of the DTT platform is generally considered as essential, and licence obligations will ensure its sustainability over time, particularly in the period to 2022.

Notwithstanding that DTT is a developed service in many countries, some national broadcasters have decided to move away from such a platform, which is deemed to cost up to 30 times more than satellite, due to costs associated with licensing and broadcast antennas, sustainable only by a high take-up. For example, Germany's largest commercial broadcaster RTL has recently announced that it is getting out of DTT broadcasting from 2014–2015.[80] This might cast doubts on the long-term sustainability of DTT, even though the German government seems to have plans to launch high-definition DTT in the long term.

All over Europe, broadcasters are currently looking for ways to distribute content more cheaply. The European Broadcasting Union has started discussions with the mobile industry to find convergent solutions over mobile broadband (e.g. LTE). Indeed, in the long term a portion of the UHF bands is expected to be designated for mobile applications. Some players are already broadcasting TV signals to mobile devices over DTT frequencies (this is the case of Nottv in Japan, or the B2M project supported by TDF in France). Results from a survey conducted by the RSPG show that in 75% of the countries surveyed (including EU-27 countries and some adjacent ones) the DTT platform is planned to evolve to being capable of delivering audiovisual services also to mobile devices. In Germany, for example, only 3% of households use DTT as the primary means of TV reception, and there are 1 million in-car TV sets and 6 million laptops equipped with DVB-T receivers. These factors could lead to the adoption of a cellular hybrid system for portable reception.

Overall, DTT is expected to remain an attractive platform over the next ten years mainly because:

- it has an established customer base; the channels available on DTT are mostly free;
- no additional equipment other than a basic TV set and antenna is required to receive DTT (such as a stand-alone decoder, an additional antenna or a phone subscription); and
- because DTT provides, thanks to technological advances, an increasingly greater number of channels and increasingly better quality of picture and sound. In particular, improvements from this point of view have been dramatic compared to analogue terrestrial;
- use of spectrum for terrestrial TV is likely to depend on commercial and policy decisions.

With the advent of higher-quality standards, the amount of spectrum currently designated for DTT may not be enough to broadcast the same (or a higher) number of channels on HDTV, in order for DTT to be able to compete effectively with other platforms such as cable or satellite. The lack of an attractive HD offer on DTT may result in consumers eventually switching to other platforms – like satellite or cable (where available) – and to ultra-fast broadband connections (as they become more widespread across Europe). However, it could be argued that the terrestrial TV spectrum could be used for mobile TV reception, as in Germany.

Technology trend	Short term	Medium term	Long term
Level of DTT adoption	=	=	=

Figure 6.29: Impact of the level of DTT adoption on spectrum usage demand

80 German broadcaster RTL has begun withdrawing DTT services to parts of the country and aims to switch off its DTT signals nationally by the end of 2014.

Take-up of DAB

Terrestrial radio broadcasting is moving to digital too, although at a slower pace than TV. Countries have started to adopt DAB and DAB+ standards to distribute radio transmissions. In the present study, we focus on the 1452–1479.5 MHz spectrum range.

Terrestrial DAB radio is becoming popular across Member States – such as in the UK (with 30% of total radio listeners listening to digital radio) – to date, the roll-out of commercial DAB radio services in the L-band has been limited (only Onde Numérique in France has announced the launch of terrestrial L-band services), and we are not aware of any S-DAB service being commercially available.

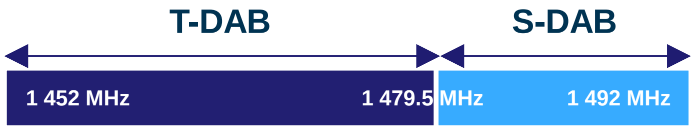


Figure 6.30: L-band spectrum designation [Source: ECO Frequency Information System]

The proportion of households with access to a DAB radio is highest in the UK, at 43% in 2012, and so is DAB coverage, at 94% of UK households. In Germany, Italy and France, DAB coverage stands at 88%, 75% and 62% of households, respectively, while penetration of DAB radio sets is still lower than in the UK. Notably, some broadcasters have started to transmit digital radio channels in DVB-T, transmitting radio signals in MUXs.

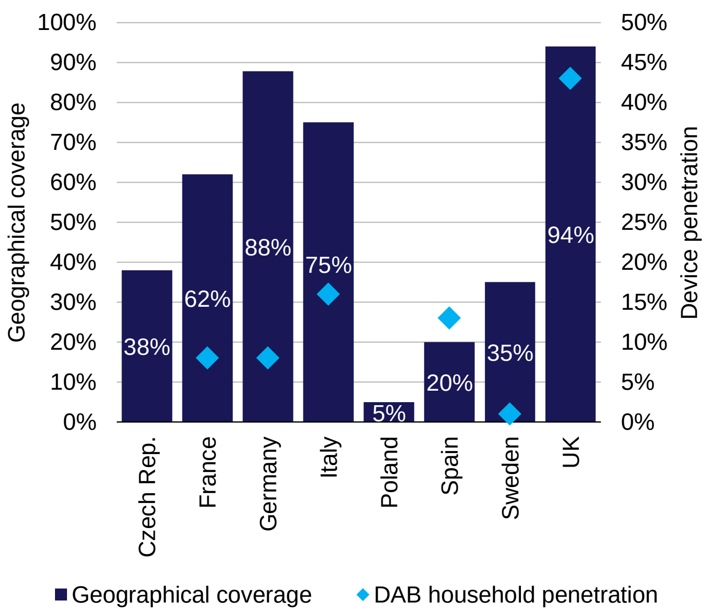


Figure 6.31: Evolution of coverage and penetration of DAB radio (2012) [Source: Ofcom, World DMB]

Penetration and coverage of DAB are expected to grow in coming years. In many countries, DAB radio is expected to be deployed in frequencies below 400 MHz, and so is likely to share spectrum with defence services. We therefore believe that DAB radio may be eventually rolled out or moved to the L-band.

Technology trend	Short term	Medium term	Long term
Take-up of DAB	=	= / +	= / +

Figure 6.32: Impact of the take-up of DAB on spectrum usage demand

Level of adoption of HDTV, 3DTV and UHDTV

The adoption of digital TV varies across Member States, depending on the TV platforms available and the timeline for the ASO (which has an impact on the amount of bandwidth available).

Penetration of HDTV sets varies across Europe, and is growing rapidly. Growth is primarily led by sales of new TV sets – e.g. almost all of the ~10 million TV sets sold in the UK in 2010 support HD. Penetration of 3DTV sets has started to increase only recently as 3D-enabled HDTV sets become available.

In the long term, it is expected that DTT transmissions will be delivered in HD. 3D services are forecast to become available on DTT in the period to 2022, such as in specific events (e.g. special sports events) and 3D movies. Nevertheless, 3DTV is expected to continue to represent a relatively minor share of the total programme offering and so should not have a significant impact on the overall DTT capacity requirements.

UHDTV delivers higher picture quality and a stronger sensation of reality than HDTV. UHDTV installations are to equip either living rooms (4K flavour) or theatres (8K flavour).

We are seeing a proliferation of HD content, but the number of movies that can be viewed in 3D is still limited. Moreover, existing technology can supports the broadcasting of any live event in either HD or 3D, but HD and 3D content requires a large amount of bandwidth. HD and 3D content is available on Blu-ray discs from pay-TV providers (mainly via satellite, but also via DTT and IPTV), and from online platforms, such as video rental services.

The installed base of HDTV sets is forecast to double in five years (2012–2017). At the same time, the number of HD channels is expected to keep growing in future in several European countries. Driven by cable and satellite operators' adoption of HDTV, DTT channels will also adopt HDTV to remain competitive.

Figure 6.33: Households with HDTV sets in the EU [Source: Analysys Mason, 2013]

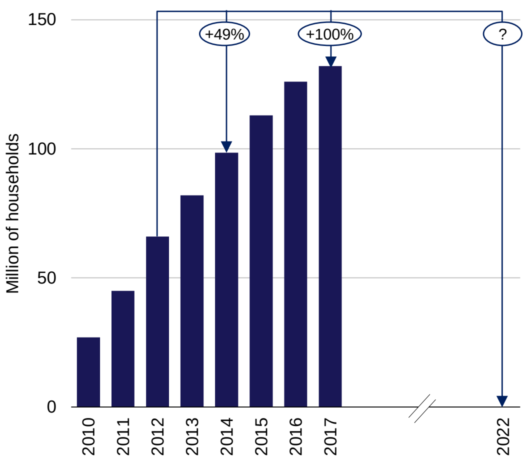
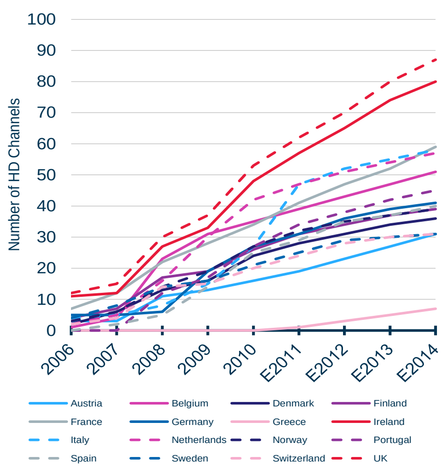


Figure 6.34: Evolution of the number of HD channels in Europe [Source: European Broadcasting Union, Screen Digest]



In the countries analysed, between 2 and 20 HD channels are available on DTT. There are no specific plans in place to deploy 3D on DTT, except for the UK, where some live events are occasionally broadcast in 3D. There are some plans to launch UHDTV in the long term – in France, for example, the launch of UHDTV is subject to the introduction of higher-compression and transmission standards.

Figure 6.35: Path to HD DTT across the countries analysed [Source: RSPG questionnaires, 2012]

Member State	HDTV	3D	UHDTV
Czech Republic	2 channels More channels possible	Not foreseen	Not foreseen
France	12 channels	-	In the long term (subject to DVB-T2 / HEVC)[81]
Germany	In the long term	Not foreseen	Not foreseen
Italy	20 channels	-	-
Poland	2 channels	-	To be defined
Spain	7 channels	Trials[82]	Trials
Sweden	8 channels (DVB-T2)	-	-
UK	5 channels	Trial broadcast of events	-

The increasing take-up of high-quality transmissions, supported both on the end-user side by the introduction of advanced TV sets, and on the production side, will lead to an increased demand for HD and UHD content. This is turn will lead to a significant increase in spectrum usage if it is not supported by higher-compression standards. In practice, higher compression standards will reduce the need for spectrum.

Technology trend	Short term	Medium term	Long term
HDTV/3DTV adoption	+	++	++

Figure 6.36: Impact of HDTV/3DTV adoption on spectrum usage demand

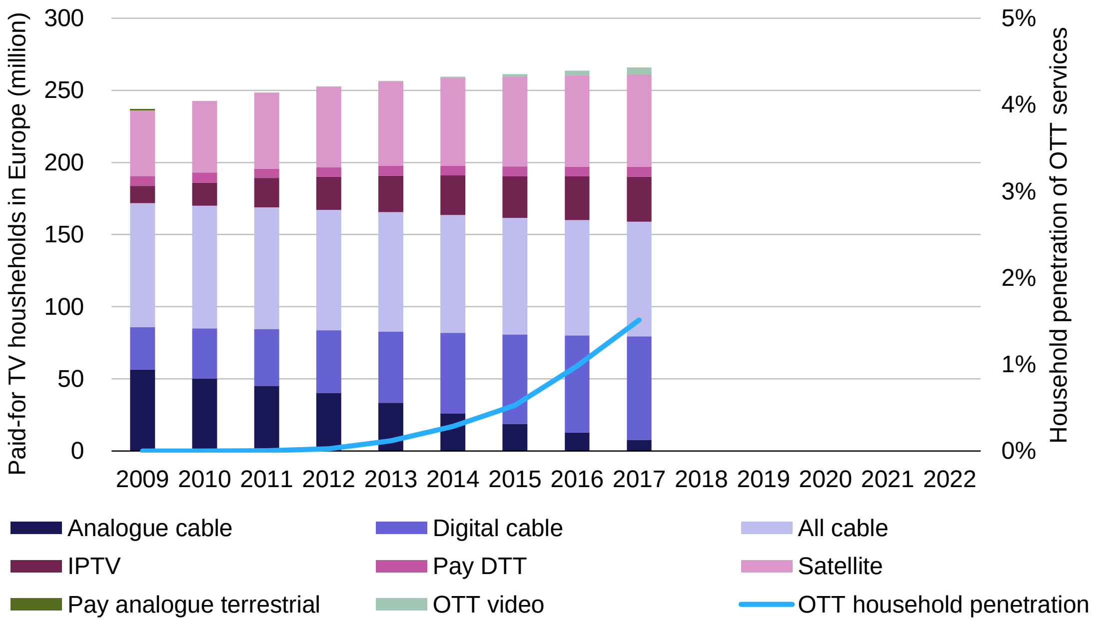
Level of adoption of OTT services and impact on DTT

Penetration of paid-for OTT services in Europe is forecast to remain constant at 2% until 2017 (see Figure 6.37), while FTA TV over the Internet is expected to continue to grow rapidly. However, free online and OTT TV services are expected to grow faster but be complementary to traditional linear TV, including DTT. Therefore, it is not envisaged that it will reduce demand for linear TV channels on DTT in coming years.

81 French regulatory body CSA envisages introduction of DVB-T2 / HEVC standards in 2018, with a transition window possibly terminating in 2025

82 Source: comment from Broadcast Network Europe

Figure 6.37: Household penetration of primary services by pay-TV platform in Europe [Source: Analysys Mason]



Thus, our base case assumes that OTT services will not have an impact on spectrum demand for DTT over the studied period.

Technology trend	Short term	Medium term	Long term
OTT services	=	=	=

Figure 6.38: Impact of OTT services on spectrum usage demand

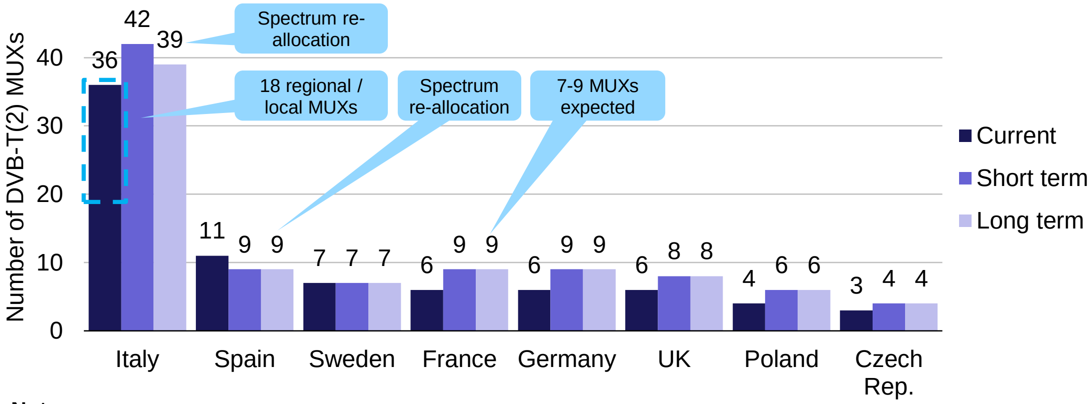
Number of MUXs

Ultimately, the number of TV channels available on DTT will be determined by commercial and, most importantly, policy decisions. During the second half of 2012, the Radio Spectrum Policy Group issued questionnaires[83] to Member States to gather information, and prepare a draft opinion, on future spectrum requirements.

Italy has the highest number of DVB-T MUXs, as shown in Figure 6.39. Indeed, DTT is the platform of choice by Italian consumers, given the lack of cable infrastructure and because fast broadband networks are concentrated in a few high-density zones. In terms of national MUXs, Italy has twice as many MUXs as any of the other countries analysed. In addition, there are a large number of regional and local MUXs, although the regulator has decided to reassign three of those MUXs to free up spectrum for mobile services in the long term.

83 RSPG (2012), *The long term spectrum requirements for television broadcasting in the European Union including the number of TV services, HDTV, interactive services, mobility requirements and the possible introduction of Ultra High Definition Television*.

Figure 6.39: DVB-T and DVB-T2 MUXs in the main focus countries [Source: RSPG questionnaires]



Notes
Italy: regional / local MUXs use spectrum equivalent to 18 national MUXs (source: Ministry of Economic Development); 1 DVB-H MUX (excluded); decrease in the l.t., partial re-allocation of the 700 MHz band to mobile
Spain: 8 national, 2 regional, 1 local; decrease in the s.t., re-allocation of the 790 - 862 MHz band to mobile
Sweden: there are only national MUXs
France: envisaged 7 to 9 MUXes, in the long term
Germany: 1 national, and 5 regional; 3 local MUXs excluded from chart (6-15% coverage)
UK: there are only national MUXs; 1 local (50% UK coverage), and 1 regional (78% North. Irel.), in the short term
Poland: 2 additional MUXs in the short / long term may be either national or regional
Czech Republic: there are only national MUXs

The number of MUXs is increasing in each of the focus countries. While spectrum is generally available for additional channels in Europe, in Italy it is already a scarce resource, thus careful planning is necessary to ensure efficient use of the spectrum. One operator controls a DVB-H licence, which is not used commercially and may be converted into DVB-T or DVB-T2, freeing up additional spectrum.

If on the one hand the introduction of more advanced standards, such as DVB-T2, could help to cope with the spectrum shortage, on the other it is expected to encourage the proliferation of new channels or the move towards higher standards of quality. As it can be seen from Figure 6.40, there are plans to increase the number of MUXs in five of the eight focus countries in the medium to long term.

Technology trend	Short term	Medium term	Long term
Number of MUXs	+	+	+

Figure 6.40: Impact of the number of MUXs on spectrum usage demand

Digital TV switchover in CEE

Digital switchover involves the process of switching from analogue to digital TV broadcasts. Digital broadcasts allow for increases in spectrum efficiency, which translates into a greater number of TV channels at higher video and audio quality.

In Europe, the digital switchover has had a significant impact on the structure of the TV broadcast market, introducing competition and enhancing reception and content quality. At the beginning of 2013, 24 of the EU-27 countries had completed the switch-off of analogue broadcasts. Bulgaria, Poland and Romania are expected to complete the ASO during 2013.

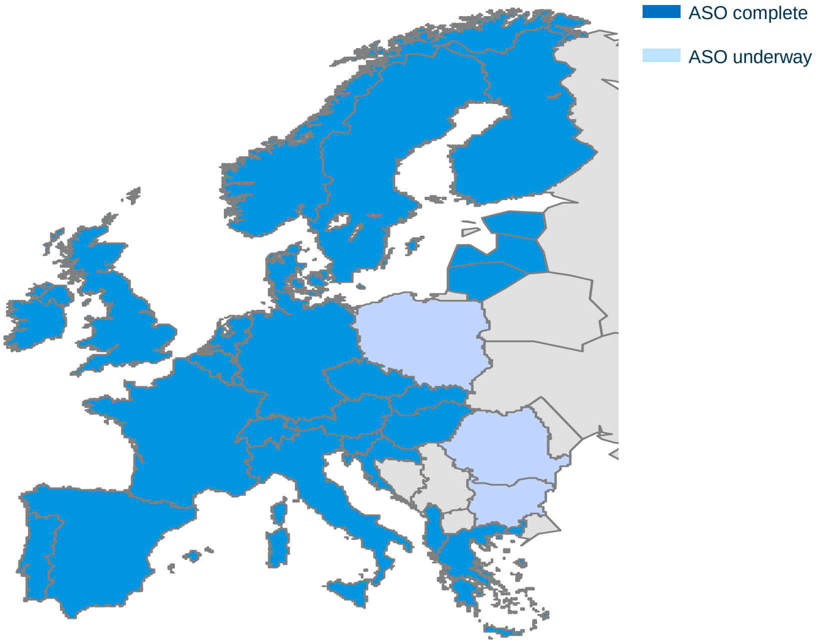


Figure 6.41:Status of the ASO in the EU-27 [Source: Analysys Mason]

The consequences of the switch to digital broadcasting are two-fold. In the short term, simulcast of analogue and digital signals results in an increase in spectrum use, while in the medium to long term, as analogue signals are switched off, overall the demand for spectrum is expected to remain unchanged.

Technology trend	Short term	Medium term	Long term
DTT/DSO	= / +	=	=

Figure 6.42: Impact of DTT/DSO on spectrum usage demand

Technology migration path (higher-quality standard and greater efficiency/compression)/ simulcast

The move to higher-quality TV channels (HDTV, 3DTV and UHDTV) is achieved with the introduction of higher compression and encoding standards.

Digital TV supports the introduction of higher video and audio quality standards at consumer level. Improved radio transmission efficiency and encoding standards pave the way to better use of spectrum. The former allows for wider bandwidths per unit of spectrum; the latter allows packing more information per bit.

DVB-T2 offers higher spectrum efficiency than DVB-T, leading to a wider bandwidth per MUX (~45Mbit/s, with 256-QAM modulation), compared to DVB-T (~27Mbit/s, with 64-QAM modulation). Also, the spectral efficiency can be further improved if multiple-input multiple-output (MIMO) antennas are used.

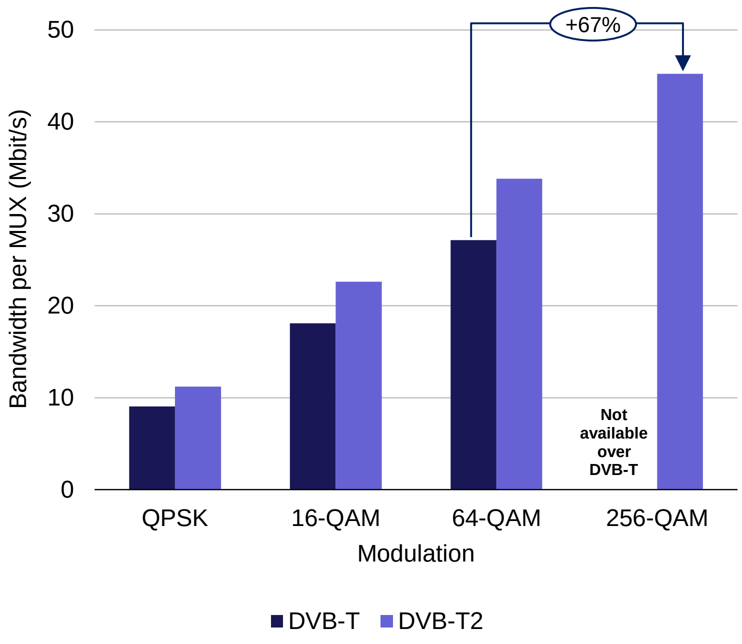


Figure 6.43: Average bandwidth available per MUX, DVB-T vs. DVB-T2 (8 MHz channel) [Source: EBU, Eluhua]

The evolution of video encoding standards and audio compression techniques allows for the reduction of data generated per unit of transmission broadcast. As a result, the bandwidth available can be used more efficiently, which means that multiple or higher-quality services/channels can be transmitted over a single multiplex. Current video compression standards already in use for high-quality transmissions (i.e. MPEG-4)[84] may not be compressed enough to support more elaborate and quality-rich formats, such as UHDTV. The introduction of improved codecs, such as the high efficiency video codec (HEVC), will contribute to solve this problem – HEVC aims to achieve a factor-of-two improvement in compression efficiency in comparison with MPEG-4.

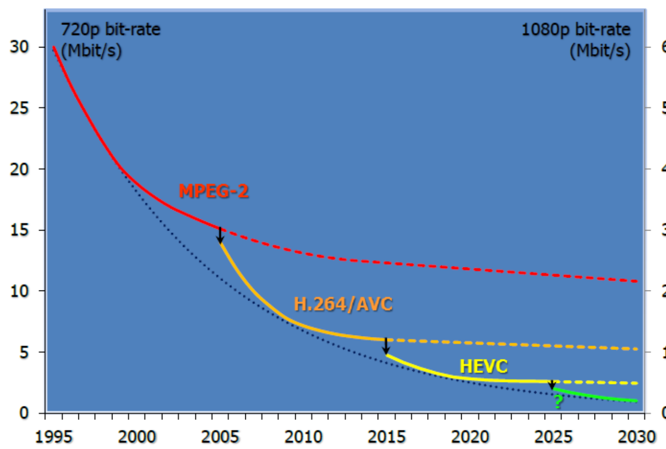


Figure 6.44: Bitrate demand trends for different compression standards [Source: ZetaCast, Ofcom, 2012]

Even if new technologies can achieve higher spectral efficiency, the full benefits will only be realised once broadcasters and viewers switch to the more advanced standards. During the period of introduction of a new standard, old and new technologies coexist (simulcast), channels are

84 Also known as H.264 / AVC. This compression format has been developed in conjunction by the Moving Picture Experts Group and the ITU-T Video Coding Experts Group

broadcast in different qualities, almost duplicating bandwidth use. Such an approach mitigates the potential benefits, which can only be fully realised in the long term, and also introduces a peak of demand during simulcast that can last for several years (typically a replacement cycle for STB and TV sets can vary from two to three to seven to ten years).

We therefore conclude that technology migration path has a significant impact on spectrum usage. The migration path will vary by country, but overall there seems to be a net impact on spectrum usage demand (due to the increase in video bitrates), as increased quality and compression are adopted. For example, if all transmissions switched to HEVC at a 1080i resolution, the bandwidth required would be 1.4x the one demanded in an MPEG-2 at 576i setting (SDTV). If the resolution were augmented to 1080p, then bandwidth demand would be 2.9x that in SDTV.

Figure 6.45: Bandwidth multipliers (MPEG-2 at 576i=1) [Source: Analysys Mason, 2013]

			Multipliers		
Standard	Resolution	Mpixel/s	MPEG-2	MPEG-4	HEVC
UHDTV	*4K*	415	**40.0**	**17.8**	**11.5**
HDTV	*1080p*	104	**10.0**	**4.5**	**2.9**
HDTV	*1080i*	52	**5.0**	**2.2**	**1.4**
HDTV	*720p*	46	**4.4**	**2.0**	**1.3**
SDTV	*576i*	10	**1.0**	**0.4**	**0.3**

However, if we consider demand for additional MUXs and take into account the introduction of more efficient transmission standards, such as DVB-T2, demand for spectrum is likely to be lower than for bandwidth.

Figure 6.46: MUX multipliers (MPEG-2 at 576i over DVB-T =1) [Source: Analysys Mason, 2013]

			Multipliers		
Standard	Resolution	Mpixel/s	MPEG-2	MPEG-4	HEVC
UHDTV	*4K*	415	**40.0**	**17.8**	**11.5**
HDTV	*1080p*	104	**10.0**	**4.5**	**2.9**
HDTV	*1080i*	52	**5.0**	**2.2**	**1.4**
HDTV	*720p*	46	**4.4**	**2.0**	**1.3**
SDTV	*576i*	10	**1.0**	**0.4**	**0.3**

It is envisaged that newer standards will keep emerging in future. It can thus be expected that the demand for bandwidth may increase more than currently projected, which may translate into greater demand for spectrum usage (to the extent that it is available, otherwise some policy decisions will need to be taken).

Technology trend	Short term	Medium term	Long term
Technology migration path	+	++	++

Figure 6.47: Impact of the technology migration path on spectrum usage demand

6.3 Cellular/BWA (Mobile)

Analysts expect a significant increase in mobile traffic over the next five to ten years, mainly driven by technology trends and user adoption. As technologies evolve, mobile data speeds increase and more services become attractive to the market (e.g. video services are expected to expand substantially with the introduction of LTE). This will have an impact on demand for new services, increasing the amount of traffic generated per user. Technology advances increasing spectrum efficiency are expected to cope only partially with the growing demand for mobile data traffic. Therefore, demand for spectrum usage is expected to grow despite these advances. Overall, future demand for spectrum for mobile will mainly depend on:

- strong adoption of more sophisticated devices such as smartphones and tablets, improved customer experience and higher data speeds
- extent of usage of more data-intensive applications on the move (e.g. not nomadic, as this can be accommodated more easily via Wi-Fi and fixed networks)
- extent of the traffic offloaded to Wi-Fi (by customers or by operators) and small-cell solutions (e.g. femtocells)
- developments of the mobile ecosystem in areas such as white spaces and spectrum sharing
- introduction of 3.5G/4G (LTE/LTE-Advanced) technologies and the associated new spectrum usage.

Figure 6.48: Summary of spectrum demand drivers for mobile applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

Mobile	Short term	Medium term	Long term
Strong adoption of more sophisticated devices	+	++	++
Adoption of data-intensive mobile applications	++	++	++
Increase of mobile data speeds	++	++	++
Adoption of M2M	=	=	=
Growth in Wi-Fi offload	-	--	--
Deployment of femtocells	= / -	= / -	= / -
Launch of LTE/LTE-Advanced	+	+	+
Number of mobile network operators	=	= / -	= / -
Spectrum sharing and white spaces	=	-	-
OVERALL ASSESSMENT	**+**	**+/++**	**+/++**

As shown in the table above, we believe that there is likely to be a net increase spectrum usage demand across all the periods considered, with an accelerated pace towards the long term, despite some partial efficiency gains, as new devices and services consolidate.

Strong adoption of more sophisticated devices

The last five years have seen the mass-market success of devices such as smartphones and tablets. As a result, manufacturers will continue to design and manufacture more sophisticated devices that encourage higher data consumption, by integrating:

- a larger screen for better video
- more powerful chipsets and operating systems allowing more sophisticated applications
- multi-band radio chipsets for maximum LTE coverage
- higher levels of performance.

These factors will be compounded by the increase in penetration of such devices and the associated user trends. This is a global trend, notwithstanding significant differences in smartphone and tablet penetration among Member States. As an example, it is expected that the number of smartphones will significantly increase in the next five years and, together with smaller contributions from tablets and mobile broadband devices, the total number of Internet-enabled mobile devices in Europe will grow by 40% in the short term and nearly 80% in the medium term.

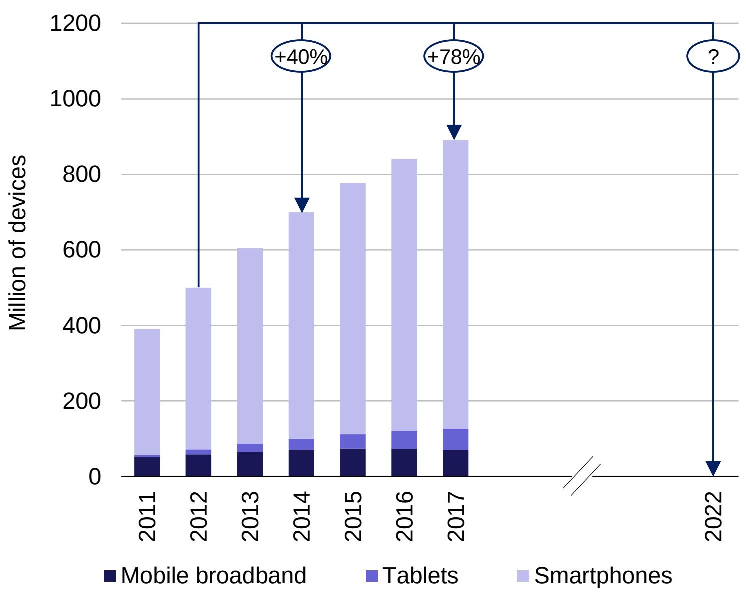


Figure 6.49: Number of Internet-enabled mobile devices in Europe, 2011–2017 [Source: Analysys Mason, Cisco]

Technology trend	Short term	Medium term	Long term
Adoption of more sophisticated devices	+	++	++

Figure 6.50: Impact of the adoption of more sophisticated devices

Adoption of data-intensive mobile applications

The increasing adoption of smart devices with larger screens and higher processing power, will in turn drive the adoption of more sophisticated and bandwidth-hungry applications, in particular online games, live streaming of video and music, interactive maps and navigation, and social networking with enhanced sharing of photos and video content. The apps market is growing very fast: the number of apps downloaded from the Apple App Store grew at about 5 billion per quarter during 2012 and topped 40 billion by January 2013. Many of these apps will be using greater data capabilities over time, and thus can be used as an underlying indirect indicator of usage growth.

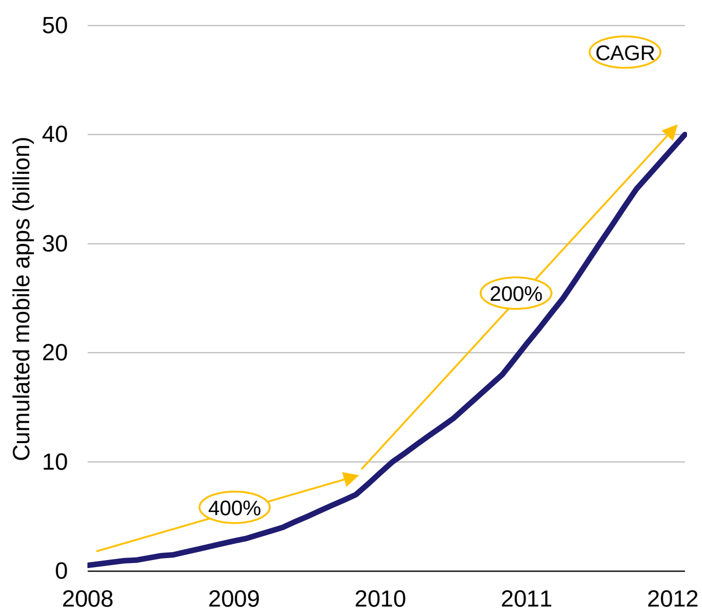


Figure 6.51: Cumulative number of mobile apps downloaded globally for the Apple platform, 2008–2012 [Source: Apple, Mashable, Analysys Mason estimates]

Another example, specifically related to video services, is the BBC's internet television and radio service and software application iPlayer, which has seen requests by consumers more than double between 2009 and 2012, growing at a CAGR of 32%. Furthermore, the proportion of requests from mobile and tablets has risen from 6% to 21%, in the same period.

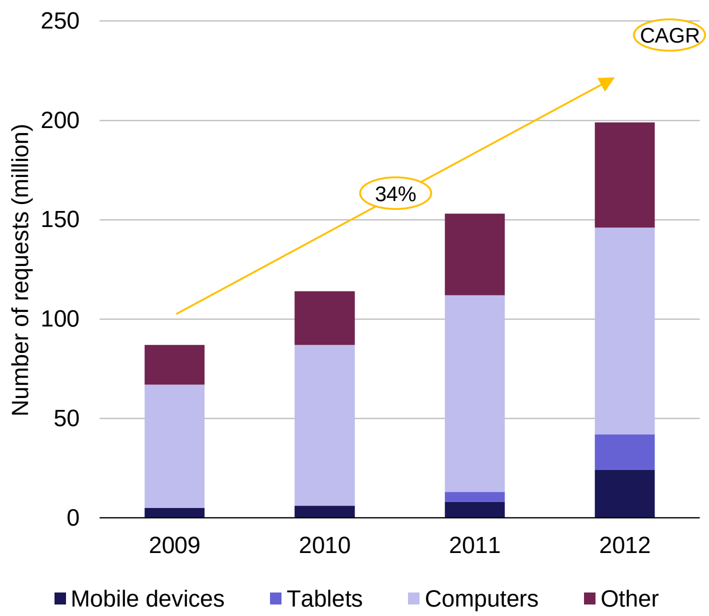


Figure 6.52: BBC iPlayer requests [Source: Analysys Mason, 2012]

Technology trend	Short term	Medium term	Long term
Adoption of mobile applications	++	++	++

Figure 6.53: Impact of the adoption of mobile applications

Increase of mobile data speeds

There will be a strong increase in mobile data speeds delivered to consumers, of the order of more than 100% in the short term and almost 400% in the medium term (see Figure 6.54 below). This increase will be the result of multiple trends driven by the private sector and by consumers:

- manufacturers will continue to design and manufacture more sophisticated mobile devices that support higher data rates
- network operators will make higher data rates available thanks to technological developments (e.g. LTE)
- consumers will adopt these advanced devices, a trend led by tech-conscious early adopters and then followed by the mass market, in line with the natural device replacement cycle.

This trend is expected to continue in the short and medium term. In particular, Cisco expects that mobile data speeds in Western Europe will almost triple in the next two years (short term) and potentially increase a six- or seven-fold in the medium term

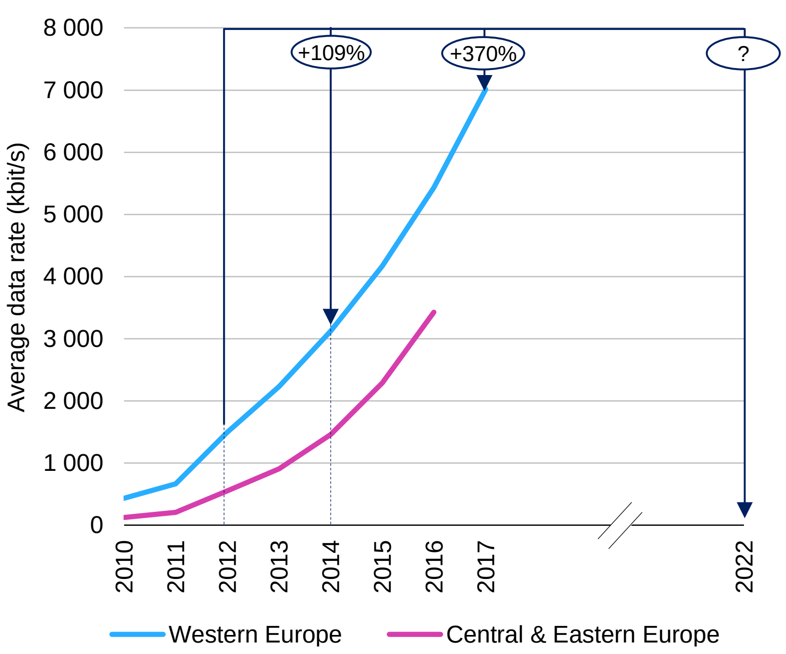


Figure 6.54: Average data speeds delivered to mobile devices [Source: Cisco VNI, 2013]

This increase in mobile data speeds is likely to encourage users to consume more data in general, as well as increase the adoption and usage of more data-intensive applications. In fact, according to Cisco, "*there is anecdotal evidence to support the thesis that usage increases when speed increases, although there is often a delay between the increase in speed and the increased usage, which can range from a few months to several years*".

We also note a significant gap between speeds in Western and Eastern Europe; this is likely to remain, and may even increase as operators in Western Europe roll out 4G more rapidly than their Eastern European counterparts. In fact, while the current and historical speeds we quote are based on data from Cisco's speed tests, our forward-looking projections are based on forecasts for the technology split (2G, 3G, 3.5G and 4G) of devices, so clearly the expected take-up of LTE devices will have a marked impact on the speed forecasts.

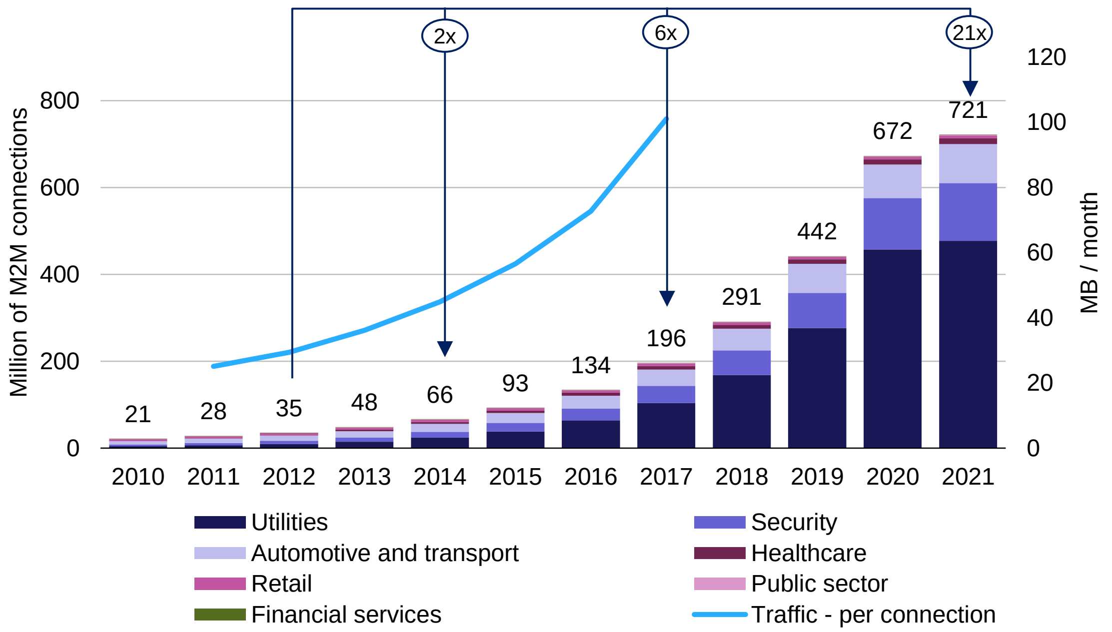
Technology trend	Short term	Medium term	Long term
Increased mobile data speeds	++	++	++

Figure 6.55: Impact of increased mobile data speeds

Adoption of M2M

At the end of 2012, there were 35 million M2M connections in Europe. We estimate that by the end of 2021, this number will increase to 720 million, implying a CAGR of 40%. Applications in the Utilities sector are expected to account for 66% of M2M connections by 2021 (a CAGR of 54% over 2012–2021).[85] Smart metering is set to become the primary driver of M2M growth within this vertical. Security solutions will account for 18% of overall M2M connections by 2021 (a CAGR of 39%), and the Automotive and Transport sector will account for 12% of connections (a CAGR of 25%). Trends in Europe are similar to those in other developed markets.

Figure 6.56: Forecast of M2M connections in Europe, by vertical, 2010–2021 [Source: Analysys Mason]



Our estimates indicate that by 2012 the average M2M module will consume circa 100MB per month, up from 30 megabytes in 2012. This is eight times less traffic than a smartphone and 14 times less than a 4G device. According to Cisco VNI,[86] by 2017 M2M communications will account for 5% of total mobile data traffic, a growth of two percentage points with respect to the end of 2012. Because M2M only represents a small proportion of traffic, it is likely to have a neutral impact on the demand for spectrum use, despite the exponential growth in the number of M2M connections.

85 German truck toll system operator Toll Collect expects its 2G data traffic to grow at a CAGR of 59% in the period 2014-2022.

86 Cisco Visual Networking Index: Global Mobile Data, Traffic Forecast Update, 2012–2017

In 2010, 90% of M2M modules were based on 2G technology:[87] this was chosen due to the maturity of the technology, its affordability, the extensive nature of 2G coverage, and the fact that it was considered more reliable than 3G. While the communication modules in M2M devices account for 2%–13% of the total cost of ownership (depending on the complexity of the application), they may be integrated in such a way that it becomes difficult or too costly to replace 2G modules with 3G or 4G ones. For this reason, the current M2M user base may require that 2G be not switched off before the end of the useful lifetime of the devices in use. Therefore, even if M2M applications require only little spectrum to operate (and thus will not demand additional spectrum), the delay in 2G switch-off may mean that the systems will be operating below the efficiency standards current at the time, which will waste spectrum.

Technology trend	Short term	Medium term	Long term
Adoption of M2M	=	=	=

Figure 6.57: Impact of the adoption of M2M

Growth in Wi-Fi offload

Wi-Fi modules are increasingly being integrated into phones, tablets, laptops, TV and other consumer device. Wi-Fi capabilities have become standard in both high-end and medium-priced devices. Moreover, it is estimated that 65% of tablets access the Internet only on Wi-Fi, 27% via a combination of Wi-Fi and mobile access, and the remaining devices are either connected via mobile-only, or are offline.[88]

Smartphones are expected to comprise only about one-third of Wi-Fi device shipments in 2017, with the rest being from tablets, laptops, M2M devices, TVs and other connected home devices.

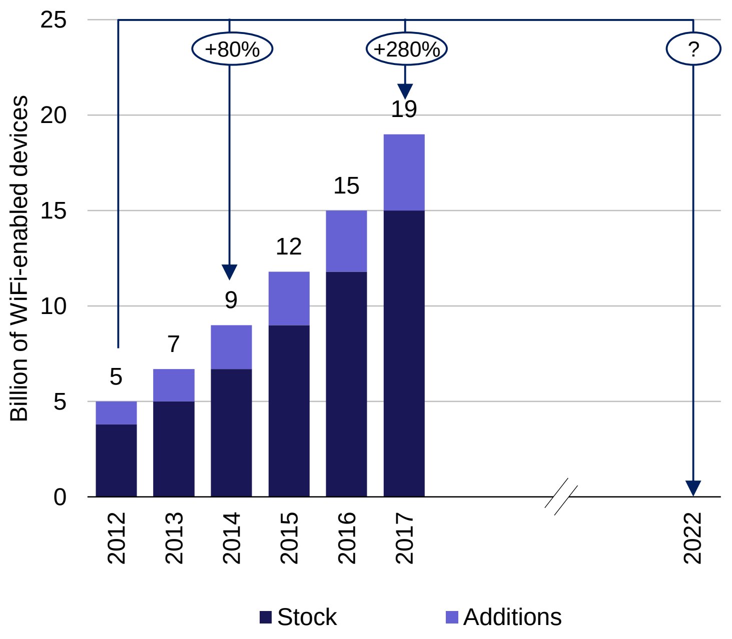


Figure 6.58: Shipments of Wi-Fi-enabled devices, 2012–2017 [Source: Analysys Mason, 2013]

87 http://www.gsma.com/newsroom/wp-content/uploads/2012/06/tcoembeddedmobilereport.pdf

88 Connected Intelligence, December 2011. See https://www.npd.com/wps/portal/npd/us/news/press-releases/pr_111212

The increase in the number of Wi-Fi-enabled devices, together with the increasing number of hotspots (for outdoor Wi-Fi offloading) and fixed broadband penetration (for indoor Wi-Fi offloading) will increase the chances of traffic being offloaded onto Wi-Fi networks. A number of facts support this conclusion:

- According to a survey of 1000 users conducted by Analysys Mason in 2012, 59% of traffic is handled through Wi-Fi networks, and the rest through cellular networks.
- In January 2011, O_2 announced that it would start to roll out its own Wi-Fi hotspots to offload data traffic in congested areas.
- Many pay-TV operators (whether using cable, IPTV or satellite platforms) are actively developing their Wi-Fi strategies, which would reinforce the trend for off-loading. During the Cable Congress 2013 some cable operators expressed the need for more Wi-Fi spectrum in the future.
- During the Mobile World Congress in 2013, Cisco indicated that it expects the amount of traffic offloaded onto Wi-Fi to be much greater than it previously thought, and as a result it rebalanced its mobile traffic forecasts (spectrum usage) between the licensed mobile spectrum of operators and Wi-Fi spectrum.

We can conclude that a substantial proportion of the traffic generated by mobile devices is and will be offloaded onto fixed networks, either via Wi-Fi access points or femto/picocells. The volume of offloaded traffic will be driven by:

- the increasing penetration of Wi-Fi-enabled devices
- the growth in the number of hotspots
- the increase in fixed broadband penetration.

Despite the 'Wi-Fi effect', demand for mobility is on the rise and, in 2017, 34% of tablets are expected to be connected with mobility, up from 29% in 2012.

Mobile-to-Wi-Fi offload is envisaged to be a growing trend, which may reduce the demand for mobile capacity. Cisco VNI forecasts that in 2017 mobile offload will account for 46% of the total traffic generated through mobile devices, up from 33% in 2012. Mobile data traffic without this offload would grow at a CAGR of 74%. However, when including offload, over the same period pure mobile data traffic is forecast to grow at a still significant CAGR of 66%.

Technology trend	Short term	Medium term	Long term
Growth in Wi-Fi offload	-	--	--

Figure 6.59: Impact of growth in Wi-Fi offload

Deployment of femtocells

Besides Wi-Fi hotspots, another method for offloading traffic from a mobile network is through the installation of femtocells. The idea of a femtocell is to create an area of mobile coverage within a small area, such as a home or small office. Femtocells are installed by end users, have a coverage range of 10–30 metres, and provide backhaul connection through the user's fixed broadband connection. The deployment of femtocells has been accelerating in the last few years. According to Informa, over the period 2009–2012 the number of mobile operators that deployed femtocells increased from 3 to 24 (see Figure 6.60 below), while three more have declared that they intend to deploy femtocells in the near future.[89] As of October 2012, the number of small cells (80% of which are femtocells) installed worldwide was equal to 6 million; this is slightly more than the number of macro cells (5.9 million).

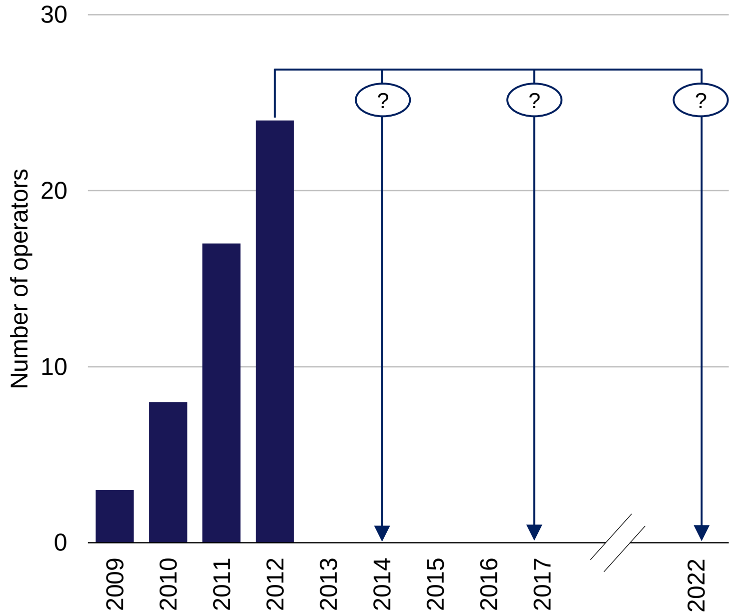


Figure 6.60: Number of operators deploying femtocells in Europe, 2009–2012 [Source: Analysys Mason, Small Cell Forum (Informa)]

Even though the trend towards femtocells is expected to continue, femtocells only provide some help to offloading traffic, as the number of users supported by a femtocell is very limited.

Technology trend	Short term	Medium term	Long term
Deployment of femtocells	= / -	= / -	= / -

Figure 6.61: Impact of deployment of femtocells

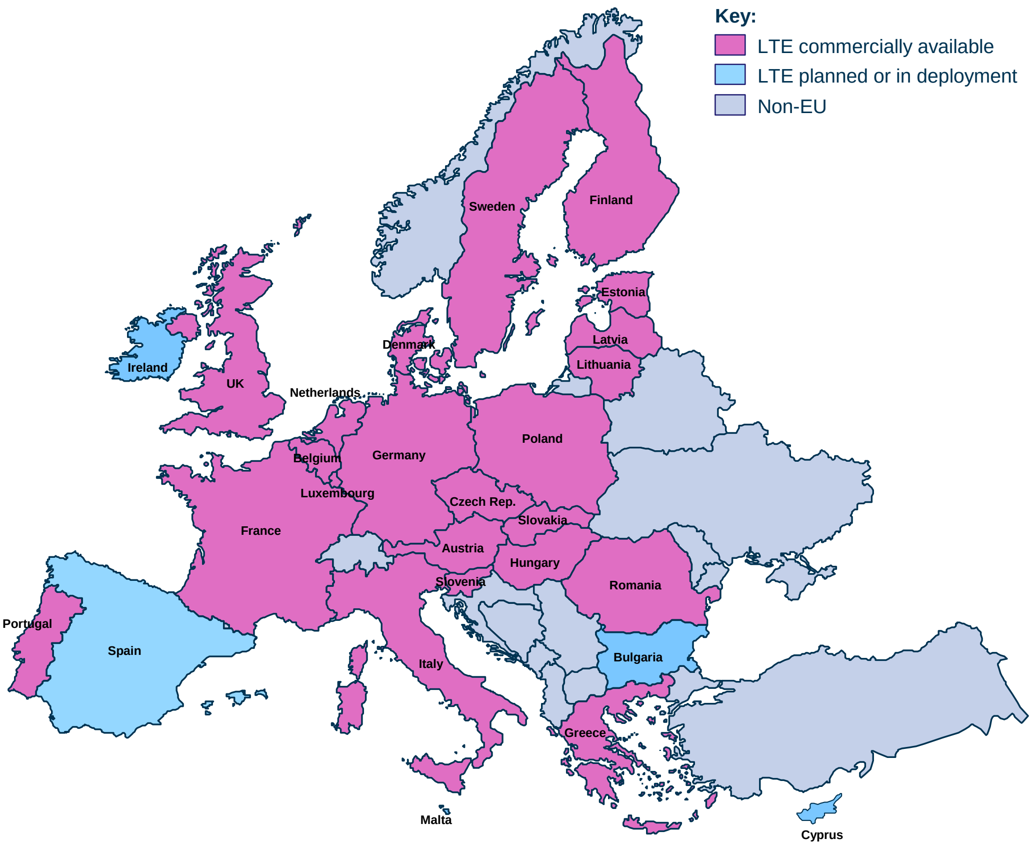
89 Informa, Small Cell Market Status, December 2012

Launch of LTE and LTE-Advanced

LTE is widely considered to be the main 4G standard worldwide, and is currently in deployment in many European countries. In terms of standards, LTE strictly refers to the Third Generation Partnership Project (3GPP) Release 8 and Release 9. LTE's extension, LTE-Advanced (Release 10 and Release 11, which is the most recent one approved by 3GPP) incorporates a number of advances which aim to give further significant gains in spectral efficiency over the next ten years.

As of January 2013, LTE had already been launched in 22 Member States, and is expected to be launched in the other five by the end of 2013, as shown in Figure 6.62 below. We do not expect LTE-Advanced to be deployed commercially on a wide scale until 2015–2017.[90]

Figure 6.62: LTE deployments within the EU as of January 2013[91] [Source: GSA, GSMA, TeleGeography, Analysys Mason, 2013]



90 The Russian operator Yota has announced the first deployment of an LTE-Advanced network within the city of Moscow.

91 LTE has also been deployed in a number of neighbouring non-EU Member States.

Although LTE is standardised for all existing bands, during the time required to migrate the subscriber base to LTE (i.e. during the next decade) all network generations will be run in parallel. For this reason, Member States have generally dedicated some additional frequencies to LTE, in particular in the 800 MHz and 2600 MHz bands, and allowed the re-farming of other bands.[92] The 800 MHz band is of particular interest, being the digital dividend freed up by the switch-off of analogue TV services. The Radio Spectrum Policy Programme (RSPP) required the authorisation process for several harmonised bands (including 800 MHz and 2600 MHz) to be carried out in all Member States by the end of 2012 (or 1 January 2013 for the 800 MHz band). However, at the time of writing the 800 MHz band is still to be designated in several Member States (e.g. Belgium, Poland, Estonia, Latvia and Lithuania), and the 2600 MHz band is still to be assigned in Slovakia, Romania, Estonia, Latvia and Lithuania. The situation is summarised in the figures below.

Figure 6.63: Progress of the 800 MHz assignment across Member States [Source: Analysys Mason, 2013]

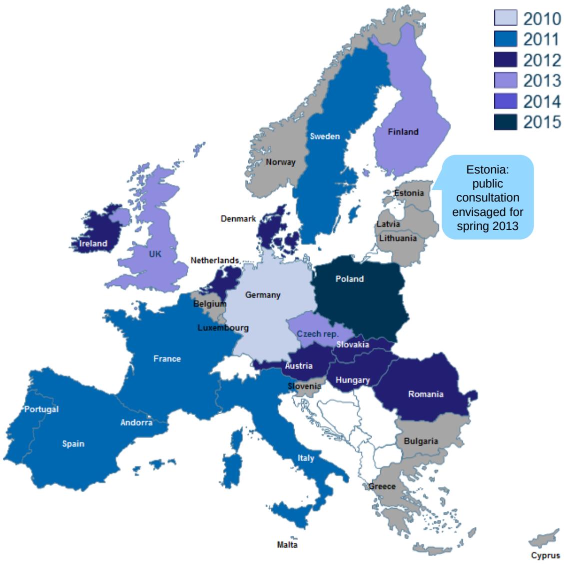
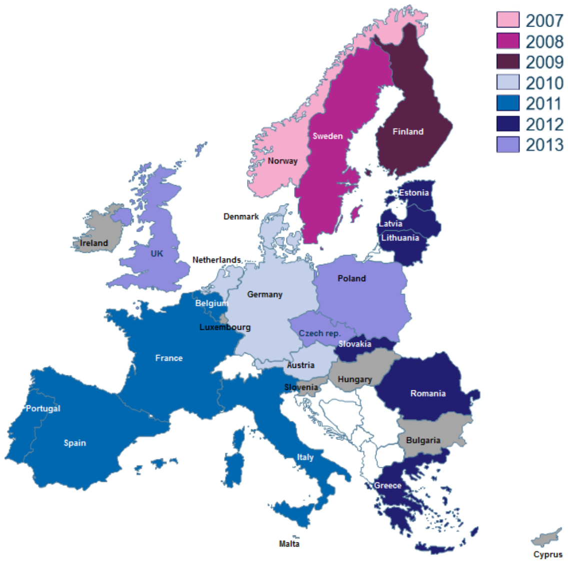


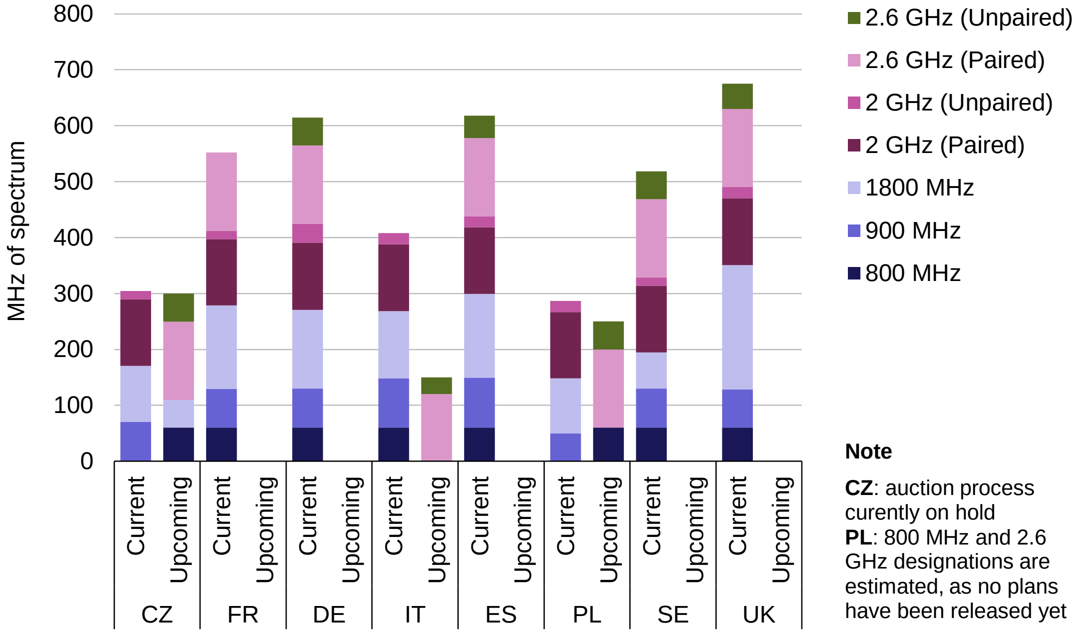
Figure 6.64: Progress of the 2600 MHz assignment across Member States [Source: Analysys Mason, 2013]



92 In some cases, 're-farming' of bands has occurred (e.g. mobile operator EE in the UK has re-designated part of its GSM 1800MHz band for LTE use).

The eight Member States considered for our detailed analysis have between 287 MHz (Poland) and 680 MHz (UK) of spectrum licensed or to be licensed in the short term to mobile services.

Figure 6.65: Spectrum designations for mobile services [Source: Analysys Mason, 2013]



Note

CZ: auction process currently on hold
PL: 800 MHz and 2.6 GHz designations are estimated, as no plans have been released yet

The launch of LTE and LTE-Advanced will offer higher speeds to mobile customers and inevitably encourage more data consumption. The net impact will be a growth in usage of the 4G-designated bands as 4G-compatible equipment becomes available and is taken up by consumers. We do not envisage that 2G and 3G technologies will be switched off within the timeframe of this study as the roll-out of LTE networks and the migration of subscribers onto them and will be gradual. Therefore 2G, 3G and LTE technologies will run in parallel, though 2G spectrum (900 MHz and 1800 MHz) will be gradually re-farmed for 3G and LTE use, to help cater for the continuous growth in mobile traffic.

Technology trend	Short term	Medium term	Long term
Launch of LTE / LTE-Advanced	+	+	+

Figure 6.66: Impact of the launch of LTE / LTE-A

Number of mobile network operators

Mobile network operators are licensed exclusive spectrum, therefore the more operators there are in a country, the more spectrum that is needed to be awarded to them. However, in most Member States mobile markets have become largely saturated and thus are unlikely to see appreciable growth in the number of operators. Most European countries host four or five mobile network operators; the situation in the eight Member States being considered is shown below.

Country	N. mobile operators	Mobile penetration
Czech Republic	4	129%
France	5	111%
Germany	4	136%
Italy	4	153%
Poland	5	131%
Spain	4	134%
Sweden	5	186%
UK	4	136%

Figure 6.67: Mobile network operators and mobile penetration (SIMs divided by population) in selected European markets [Source: Analysys Mason, 2012]

In fact the number of operators may even decline in some countries. Some operators have already started to look at consolidation – e.g. in the UK, Orange and T-Mobile merged to form Everything Everywhere. Others have network-sharing deals in place, as in the case of MBNL (H3G and Everything Everywhere) and Beacon (O_2 and Vodafone) in the UK. Consolidation and network sharing may lead to a more efficient use of spectrum, even though it is difficult to quantify the impact, due to the different types of network sharing that are possible (RAN sharing, site sharing, core sharing and spectrum pooling) and geographical extent to which it takes place (e.g. in urban or rural areas, only in greenfield sites, or across the whole country).

Each mobile player is allocated a fixed amount of spectrum which may not depend on the final usage intensity within that spectrum. Indeed, operators tend to bid for more blocks than the ones that they strictly need, in order to allow for increases in demand for capacity, the possible deployment of further technologies, or to block competitors, among other reasons. This reasoning implies that operators may not make efficient use of the spectrum they have at hand: some of it may remaining unused. Therefore each new mobile operator that enters a given market will produce a decrease in the overall efficiency of spectrum use. Given market consolidation, it is expected that the number of operators will either decrease or remain equal to today's levels, leading to a stabilisation of spectrum demand.

Technology trend	Short term	Medium term	Long term
Number of mobile network operators	=	= / -	= / -

Figure 6.68: Impact of the number of mobile network operators

Spectrum sharing and white spaces

More spectrum would be available for mobile applications (in particular for mobile broadband) if mobile operators and other communities could share their spectrum (within the bands designated to mobile and also within other bands) or exploit the so called white spaces, i.e. portions of licensed spectrum that are not being used the primary licensee at a certain time, in a particular area. In particular, there is growing interest in the industry in exploiting the white spaces in the UHF band, which is designated for broadcast services. The most important applications enabled by white-space devices would be enhanced Wi-Fi, rural broadband and M2M.

Spectrum sharing and the use of white spaces will allow for a more efficient use of spectrum, and may lower the demand from mobile services for exclusive spectrum (or increase the use of alternative spectrum). Therefore, although these developments may not affect spectrum usage per se, they might reduce usage of licensed mobile bands.

The Commission has proposed a regulatory approach to foster spectrum sharing (including white spaces) and licensed shared access (LSA). A draft RSPG opinion on LSA will be ready for consultation in June 2013. In Europe, Ofcom has taken the lead in the development of the white-space ecosystem in the UHF band, in which digital terrestrial TV and PMSE operate. Other countries in Europe such as Finland and Germany are also looking at white-space regulation. In its consultation of November 2012, Ofcom proposed a license-exempt regime for white-space devices, and the use of a geo-location model based on an online database of usable frequencies.

These developments are promising, but given the slow pace at which the ecosystem is evolving, the impact of spectrum sharing and white spaces is expected to be negligible in the short term, and may bring benefits only in the medium to long term.

Technology trend	Short term	Medium term	Long term
Spectrum sharing and white spaces	=	-	-

Figure 6.69: Impact of spectrum sharing and white spaces

Summary

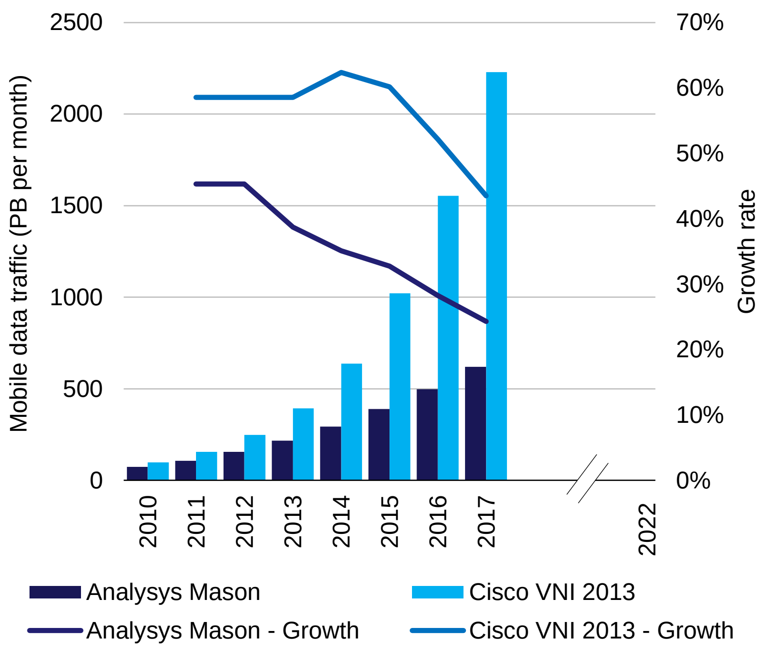


Figure 6.70: Forecast of European mobile data traffic, 2010–2017 [Source: Analysys Mason, Cisco VNI 2013, UMTS Forum, 2012]

Despite Cisco's downward revision of its forecasts for the growth of mobile data traffic during MWC 2013, and the significant growth in offloading via Wi-Fi, femtocells and other small-cell solutions, analysts expect a significant rise in mobile data traffic from consumers. Cisco forecasts mobile traffic in Europe to exceed 2000PB per month by 2017, while the UMTS Forum does not expect the 2000PB threshold to be reached until 2020. Analysys Mason is also conservative in this respect, envisaging overall mobile traffic to reach circa 600PB per month in 2017. This growth in mobile traffic will increase demand for spectrum by over 50%, starting in the short term.

Technology trend	Short term	Medium term	Long term
Growth in mobile data demand	+	+/++	+/++

Figure 6.71: Impact of growth in mobile data demand

6.4 Defence systems (defence)

The defence category encompasses a very broad range of technologies and spectrum uses, and includes demand for all systems that are used by the defence community. In some cases, these systems will use spectrum bands managed by the military; in others, commercial or other privately held spectrum bands may be used. In addition, it should be noted that, in most Member States, many military bands are shared with other civilian uses, and advances such as dynamic or shared spectrum access could lead to more efficient spectrum use in the future, both within the defence sector and cross-sector.

Overall, we expect that spectrum usage demand for defence will increase mainly due to the following trends:

- growth in the number of connected devices and in the amount of information exchanged
- development and take-up of unmanned aeronautical systems
- the implementation of new applications such as information acquisition and exchange.

Figure 6.72: Summary of spectrum demand drivers for defence applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

Defence	Short term	Medium term	Long term
Growth in activity in the Defence sector	=	+	+
Growth in information exchanged (enhanced connectivity)	=	+	++
Increase in unmanned aeronautical systems	=	+	++
Potential compression benefits from new technologies	=	= / +	+
Potential of freeing spectrum designated to Defence	=	=	=
Increase in satellite use with civil and governmental assets	+	+	++
Potential to switch to commercial services / operators	=	= / +	= / +
OVERALL ASSESSMENT	**=**	**+**	**++**

Growth in activity in the Defence sector

The Defence sector is growing due to a rising need for military action, in different areas of the world. Despite military forces operating in smaller groups, the use of highly sophisticated equipment makes for a continuous increase in spectrum usage demand.

Operational use[93] requires unceasing and live communications among team members, in order to ensure personal safety and mutual on-the-field support. Military tactics are shifting towards actions with smaller groups of skilled soldiers, who make use of prototype equipment.[94] Such devices are continually developed and incorporate the latest technologies and discoveries, and operate on large bandwidths, which drives up demand for spectrum usage.

Indeed, there exists a huge diversity within military applications:

- fixed, mobile, and satellite radio communications
- radio-navigation, using different kinds of radars
- aeronautical and weapon system functions
- identification, meteorological aids, telemetry and many others.

Overall, demand for spectrum generated by the growth in the Defence sector is increasing, driven by device sophistication.

Technology trend	Short term	Medium term	Long term
Growth in activity in Defence sector	=	+	+

Figure 6.73: Impact of growth in activity in the Defence sector [Source: Analysys Mason, 2013]

Growth in information exchange (enhanced connectivity)

Modern military operations require an enhanced level of connectivity between a proliferating number of devices, which in turn demand increasing amounts of bandwidth. For example, it is envisaged that the UK's Network Enabled Capability for Close Combat project will operate at up to 6Mbit/s, a 150x increase with respect to today's standards (40kbit/s).[95]

Military communications are deployed both on the short- and the long-haul, using fixed links, mesh networks and satellite systems. Such connections are operated across multinational operations, typically occurring between operational headquarters (OHQ), force headquarters (FHQ) and battlefields.

93 Including war fighting and peace keeping.

94 Military equipment is designed to allow for enhanced connectivity and augmented reality, and offer a common operational picture and situation awareness to all team members.

95 NATO/EDA submissions.

Overall, the growth in information exchange will push spectrum usage demand upwards, in the medium to long term. Yet, spectrum sharing may allow for reusing frequencies, while released by the Defence sector, which should retain usage priority.

Technology trend	Short term	Medium term	Long term
Growth in information exchange	=	+	++

Figure 6.74: Impact of growth in information exchange [Source: Analysys Mason, 2013]

Increase in unmanned aeronautical systems (UAS)

UAS are deployed both for defence and civil uses. Defence currently uses UAS for the deployment of drones, supposed to be operated in segregated airspace.[96]

Global budget of unmanned aeronautical vehicles (UAV) is forecast to increase year-on-year, with R&D costs representing roughly one third of the yearly expenditure. We expect the number of systems to increase in line with budget.

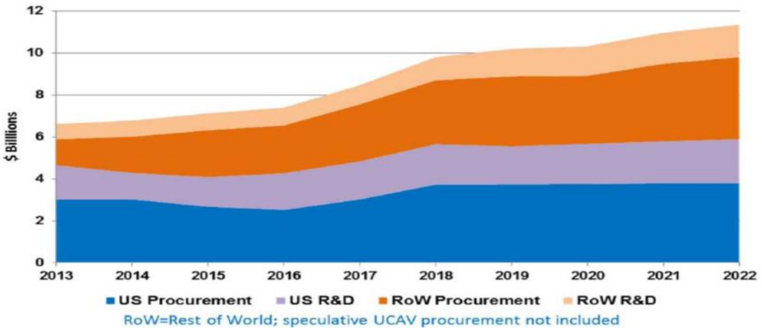


Figure 6.75: Global UAV budget forecast [Source: Teal Group, 2012]

The operation of UAS requires both beyond-line-of-sight (BLOS) and line-of-sight (LOS) communications, demanding the uninterrupted use of a large amount of bandwidth across a diverse set of geographies.

In airspace segregated for military uses, NATO harmonised bands and civil bands (such as the Ku-band) can be used concurrently to accommodate spectrum demands.[97] Within the general air traffic region (GAT), military UAS have to comply with (much stricter) civil regulations.[98]

Overall, demand for spectrum usage will increase in the medium to long term, due to the growth in the number of unmanned aeronautical systems and vehicles.

Technology trend	Short term	Medium term	Long term
Increase in UAS	=	+	++

Figure 6.76: Impact of an increase in UAS [Source: Analysys Mason, 2013]

96 Although, in general, military UAS may need to fly also in the general air traffic (GAT) region, possibly interfering with civil systems.

97 C&C, SAA and payload.

98 It can be expected that new equipment be developed allowing for wider tuning ranges, accommodating both the use of NATO harmonised bands in segregated airspace and aeronautical bands in the GAT on the same devices.

Potential compression benefits from new technologies

Research and development allow for reaching better compression techniques, supporting the transfer of greater volumes of information within the same amount of spectrum and timeframe. While on the one hand efficiency improvements lower spectrum demand, on the other hand they provide additional capability, highly demanded by upcoming complex applications. Eventually, increases in efficiency do not tend to result in spectrum being freed up.

Overall, spectrum demand is expected to increase despite the improvements in compression techniques.

Technology trend	Short term	Medium term	Long term
Potential compression benefits from new technologies	=	= / +	+

Figure 6.77: Impact of potential compression benefits from new technologies [Source: Analysys Mason, 2013]

Potential of freeing spectrum designated to Defence

Defence holds a significant amount of spectrum, often on a shared basis with civil use. Military forces appear to be returning unneeded spectrum to civil uses. For example, France has returned some spectrum, and the UK is planning to return up to 500 MHz of spectrum.[99]

Overall, since the spectrum being released is unneeded, demand for spectrum is not expected to undergo changes.

Technology trend	Short term	Medium term	Long term
Potential of freeing spectrum designated to Defence	=	=	=

Figure 6.78: Impact of the potential of freeing spectrum designated to Defence [Source: Analysys Mason, 2013]

Increase in satellite use with civil and governmental assets

There is a significant increase in the use of satellite assets. The military require the ability to get surveillance and reconnaissance information from forward areas, using satellite communications, Earth observation, integrated services routers (ISR) and positioning tools, employing a mixture of both secured governmental and commercial assets.

Overall, spectrum demand is expected to increase significantly.

Technology trend	Short term	Medium term	Long term
Increase in satellite use (governmental and civil assets)	+	+	++

Figure 6.79: Impact of the increase in satellite use (governmental and civil assets)

99 This amount of spectrum includes both Defence and government frequencies.

Potential to switch to commercial services / operators

Military-grade communications are costly to develop and deploy, as they have to be carried out in hostile environments. Besides being secure and undecipherable, devices must be almost indestructible.

While such costs may be reasonable for battlefield operations, they are not viable for civil-like operations (such as peacekeeping, training and logistics). Indeed, there are many other military uses of communications, for which the environment does not demand excessively protected nor ruggedized devices.

There is a move towards commercial off-the-shelf (COTS) procurement and commercial grade equipment. Different services (such as satellite communications) are being outsourced to commercial providers.

Overall, the potential switch to commercial services or operators is there, but is slight.

Technology trend	Short term	Medium term	Long term
Potential to switch to commercial services / operators	=	= / +	= / +

Figure 6.80: Impact of the potential to switch to commercial services / operators [Source: Analysys Mason, 2013]

6.5 Fixed links (fixed)

During the last two decades, fixed links have mainly supported the development of public mobile networks. Within this segment, the number of point-to-point links increased by 24.5% per year during the period 1997–2010. In the overall market, the number of fixed links grew on average by 6.4% per year during the period 2001–2010.[100] Demand for fixed links is expected to grow further with the introduction of new connected nodes within increasingly dense mobile networks.

Our assessment of the future demand for spectrum for fixed links mainly depends on two factors:

- The degree of substitution by fibre networks – the more widespread availability of fibre-optic connections may reduce the need to deploy fixed-link solutions. The situation is likely to vary significantly between and within countries, depending on the degree of urbanisation and the availability of fibre.
- The migration of fixed links to higher frequencies – there is a trend towards moving fixed links to frequencies above 6 GHz in order to achieve higher bandwidths, though lower frequencies may be adopted for fixed links operating in non-line-of-sight conditions. In addition, advances in modulation and coding technology may increase the capacity of fixed links, possibly leading towards a reduction in spectrum demand.

These factors are discussed in more detail below. Overall, we expect that the demand for usage of spectrum below 6 GHz will decrease in the coming years.

100 Source for data points within the present section is ECC Report 173

Figure 6.81: Summary of spectrum demand drivers for fixed links applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

Fixed links	Short term	Medium term	Long term
Microwave-to-fibre substitution	= / -	= / -	- / --
Deployment of new mobile base stations	+	+ / ++	+ / ++
Demand for higher-frequency links	- / --	- / --	- / --
Take-up of services that require low latency	=	=	=
OVERALL ASSESSMENT	**= / -**	**-**	**--**

Microwave-to-fibre substitution

The expected explosion in mobile data traffic will drive an increase in both the number of mobile base stations and the traffic per base station in the short, medium and long term. This translates into a growing need for high-bandwidth backhaul links from base stations to transport networks. These backhaul links can be either microwave links or fibre links. Where possible or viable, operators usually prefer to use fibre links as these have lower maintenance costs and greater capacity. The picture is more complex, however, due to the different economics of fibre and microwave links. In particular, the cost of a microwave link is independent of the distance covered, whereas the cost of a fibre link does depend on distance.

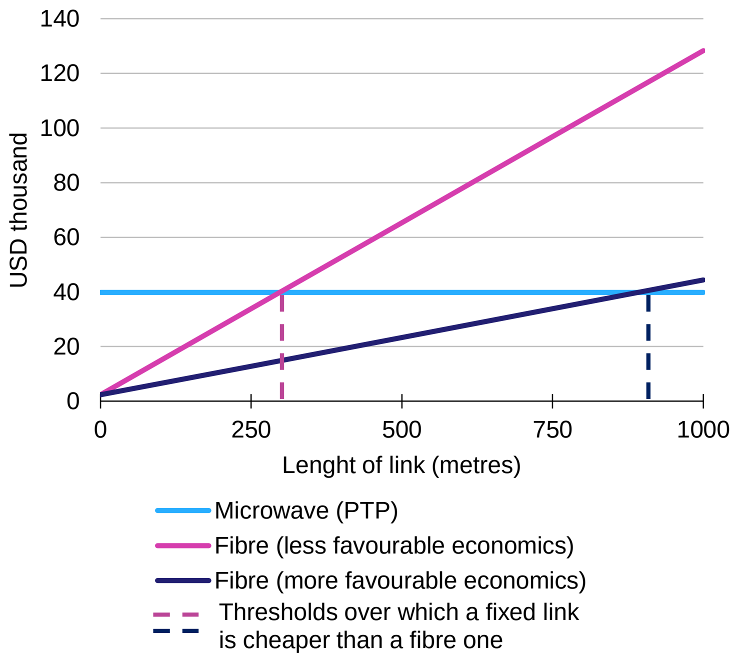


Figure 6.82: Comparison of the total cost of ownership of fibre vs. fixed links in urban areas [Source: Analysys Mason, 2013]

There are several factors that influence the cost of rolling out fibre, including:

- the degree of urbanisation and the population density in the area under consideration.
- the presence of existing infrastructure such as ducts that can be used to roll out new fibre without the need to dig further trenches (trenching makes up most of the investment in fibre roll-out).

Across Europe the population is slowly concentrating in more urban areas (see Figure 6.83), where there are already multiple fibre links and which therefore have more favourable economics for the use of fibre links. Given that the changes in the level of urbanisation are only small, the impact of this factor on the further take-up of fibre (and so the potential decrease in the number of microwave links) is limited.

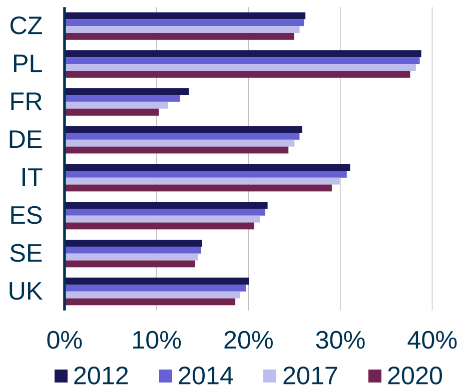


Figure 6.83: Forecast of rural inhabitants as a proportion of total population, 2012–2020 [Source: Euromonitor, 2012]

In areas where fibre is costly to roll-out or for long links (e.g. in rural areas), we expect that the shift to fibre will occur at a relatively slower pace. Given the cost of fibre, operators have been initially linking with fibre only those base stations that aggregate traffic from neighbouring base stations: remote stations are expected to keep relying on microwave links.

Despite the long-term trend to fibre, in the short to medium term microwave backhaul will still grow. For example, KPN is expected to install 15 000 microwave 'mini-links' in Germany and Belgium by the end of 2013, while Telecom Italia expects its use of microwave links to grow further, alongside fibre.

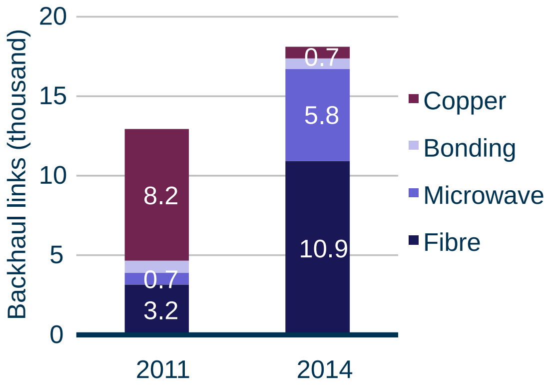


Figure 6.84: Telecom Italia's backhaul mix for UMTS/LTE sites in 2011 and 2014 [Source: Telecom Italia, 2012]

In summary, it is our expectation that some spectrum below 6 GHz that is currently used by fixed links may be freed up, either due to fibre substitution or to a change in the frequency bands employed.

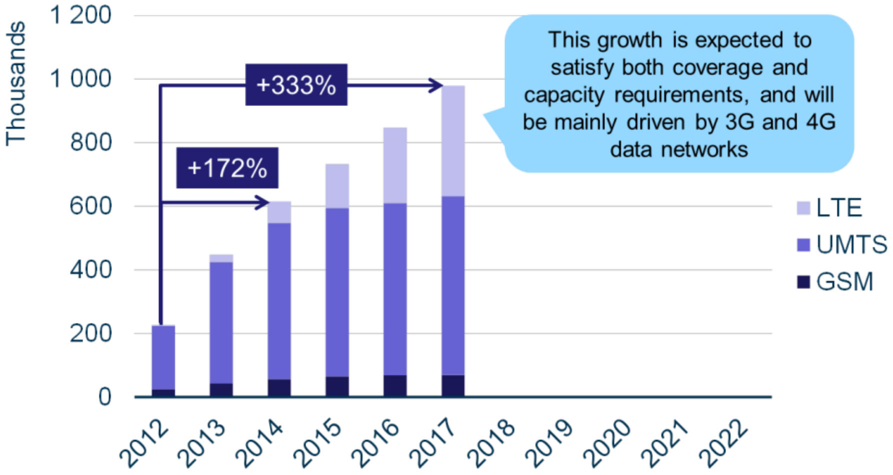
Technology trend	Short term	Medium term	Long term
Microwave–fibre substitution	= / -	= / -	- / --

Figure 6.85: Impact of microwave-fibre substitution [Source: Analysys Mason, 2013]

Deployment of new mobile base stations

Mobile operators keep developing their networks to increase both coverage and capacity. Analysys Mason expects that the number of base stations in Europe will increase by 34% per year over 2012–2017, driven mainly by the expansion of existing 3G networks and the roll-out of LTE infrastructure.[101]

Figure 6.86: Forecast of base station deployment by technology in Europe, 2012–2017 [Source: Analysys Mason, 2013]



This expansion will lead to a strong increase in spectrum usage demand. In the following subsections we consider two factors:

- the increasing use of higher frequencies (over 6 GHz) for fixed links in order to increase capacity
- increasing demand for services that require low-latency links.

Technology trend	Short term	Medium term	Long term
Deployment of new mobile base stations	+	+ / ++	+ /++

Figure 6.87: Impact of the deployment of new mobile base stations [Source: Analysys Mason, 2013]

Demand for higher-frequency links

The increasing demand for bandwidth is leading to the migration to higher-frequency links (over 6 GHz) which offer greater capacity. (There are proposals that fixed links should be operated on even higher frequencies, above 64 GHz;[102] however, these bands are outside of the scope of the present work.) Data shows that between 1997 and 2010, the number of fixed links operating in bands above 6 GHz substantially increased, and we expect this trend to continue, leading to a decrease in demand for spectrum below 6 GHz.

101 We note that, whenever possible, operators will co-locate LTE base stations with existing 3G ones, in order to avoid the investment on new physical infrastructure (tower, masts, rooftops).

102 ECC Report 173

Figure 6.88: Number of high-frequency links in Europe [Source: ECC Report 173]

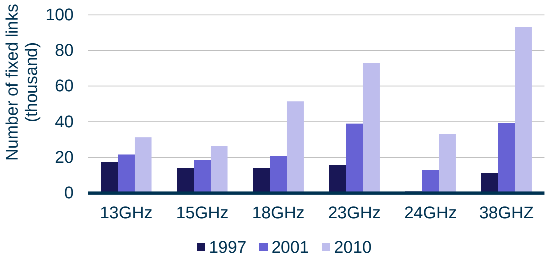
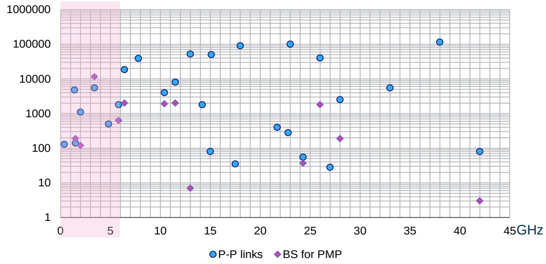


Figure 6.89: Distribution of fixed links by frequency in Europe (March 2011) [Source: ECC Report 173]



Technology trend	Short term	Medium term	Long term
Demand for higher-frequency links	- / --	- / --	- / --

Figure 6.90: Impact of demand for higher-frequency links [Analysys Mason, 2013]

Take-up of services that require low latency

There is increasing demand for services that require low-latency links, for example fault detection in smart grids, and systems for high-frequency financial trading. However, we understand that these applications will use links above 6 GHz, and so fall outside the scope of this study.

Technology trend	Short term	Medium term	Long term
Take-up of services that require low latency	=	=	=

Figure 6.91: Impact of take-up of services that require low latency [Analysys Mason, 2013]

6.6 Intelligent transport systems (ITS)

The Commission states that "*Intelligent Transport Systems or ITS means systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport*."[103]

The European Telecommunications Standards Institute (ETSI) defines ITS as telematics and all types of communications within vehicles, among vehicles (vehicle-to-vehicle or V2V), and between vehicles and fixed locations (vehicle-to-infrastructure or V2I). ITS also include the information and communication technologies used for rail, water and air transport.

ITS are a combination of technologies, allowing for the provision and sharing of on-line information across different devices employed within the transportation sector. They have the potential to enable new business models and commercial services.

[103] Directive 2010/40/EU: "*aims to establish interoperable and seamless ITS services and promote harmonisation while leaving EU Member States the freedom to decide which systems to invest in. It sets out priorities and principles for ITS deployment — but it does not oblige Member States to deploy IT systems or services on their territory*."

Such systems are used for the communication among mobility-related devices in order to ensure transit safety. Given the sensitivity of the task, it is of upmost importance for ITS to be reliable, and to have high success rates and low latency. Thus, it is required that specific frequencies be at least partially dedicated for such applications, in order to reduce likely radio interferences with surrounding radio devices.

ITS are being deployed across Europe, although in an uncoordinated way across Member States. It would be sensible to have a co-operative and unified framework to sustain a consistent development of such technologies.

The frequencies identified would be shared with other applications, such as mobile and industrial, scientific and medical (ISM).

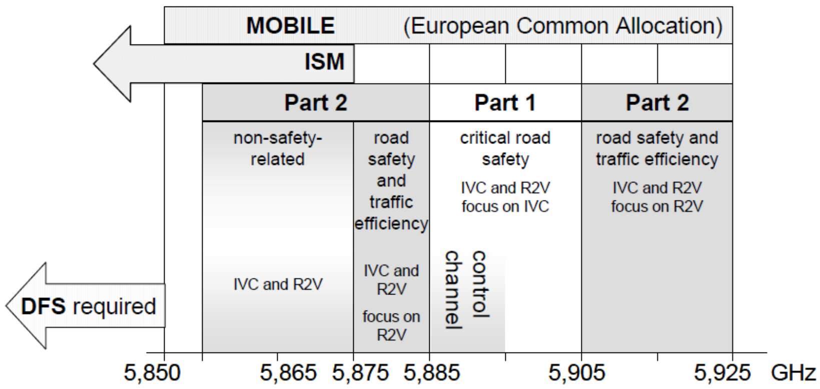


Figure 6.92: 5.9 GHz CEPT frequency requirement [Source: CEPT Report 20]

DFS: Dynamic frequency selection
ISM: Industrial, scientific and medical

The EC[104] has identified different action areas, among which we have identified two themes relevant for the present study:

- continuity of traffic and freight management
- integration of the vehicle into the transport infrastructure to ensure road safety and security.

Overall, we expect that spectrum usage demand will increase due to the wide introduction of new ITS applications and the relative growth in take-up.

Figure 6.93: Summary of spectrum demand drivers for ITS applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

ITS	Short term	Medium term	Long term
Development and take-up of ITS applications:			
▪ traffic and freight management	= / +	+	+
▪ integration vehicle-infrastructure	=	+	++
▪ new ITS applications	=	+	+
OVERALL ASSESSMENT	**=**	**+**	**++**

104 European Commission (2011), *Intelligent Transport Systems in action – Action plan and legal framework for the deployment of intelligent transport systems (ITS) in Europe*. Available at http://ec.europa.eu/transport/media/publications/index_en.htm

Development and take-up of ITS applications

The EC aims to co-ordinate the roll-out of an EU-wide and interoperable ITS network, in order to ensure seamless support to road users. The EC promotes co-operation to sustain the development of compatible systems capable of exchanging traffic data and information across borders. Such a platform would simplify travel planning and freight delivery. Specifically, the EC backs the development of interconnected services, which can assist road users during their regular travel activities.

► *Traffic and freight management*

Traffic- and freight-management solutions are supported by existing technologies, and EU-wide effective deployment can be only guaranteed by top-level co-ordination. Such solutions enable vehicles[105] and drivers to be informed of upcoming mobility-related events, and to be advised in due time in order for drivers to take the safest actions.

Some solutions have already been identified as minimum requirements for European roads and they include dynamic lane management,[106] delivery of variable speed limits, and management of both planned events and unexpected incidents. Applications of traffic management already in widespread use are, for example, vehicle-recognition transponder systems,[107] and average-speed radars.[108]

Freight-management systems allow to track goods on their way to destination and to co-ordinate their delivery across different modes of transport. The e-Freight project[109] aims to track and trace goods using technologies such as radio frequency identification and geo-localisation.

The support of the EC towards the creation of EU-consortia to provide standardised traffic and freight-management solutions across Europe represents a significant step, which could effectively back a generalised take-up of traffic- and freight-management systems across the EU.

Overall, a growth in the adoption of such systems is envisaged to lead to an increase in spectrum usage demand in the medium to long term.

Technology trend	Short term	Medium term	Long term
Traffic and freight management	= / +	+	+

Figure 6.94: Impact of traffic and freight management on spectrum usage demand

105 The application which allows road infrastructure to instruct vehicles is also referred to as V2I, which is discussed elsewhere in this report.

106 Dynamic lane management allows for dynamically dedicating road lanes to different categories of users, based on the time of day, the type of vehicle or the number of passengers.

107 Transponder systems are used to pay road tolls or to signal the identity of a vehicle transiting through a town access.

108 Average-speed radars recognise the average speed of a vehicle along a road segment, while regular speed radars identify only the instantaneous speed.

109 Funded by the EU via the 7th Framework Programme.

► *Integration vehicle-infrastructure*

Driver assistance solutions in place make use of the information stored in vehicles (e.g. navigation systems), broadcast by radio stations (such as traffic message channel (TMC)), or received by integrated sensors and radars (such as assisted-parking / emergency-braking systems), in order to deliver safety and traffic efficiency effects.

Such benefits can be further increased if vehicles were able to communicate with each other and with the road infrastructure, in order to exchange live information on traffic and weather conditions. This kind of interactions is supported by the development of co-operative systems.[110]

The EC promotes the standardisation of co-operative systems, which allow for the creation of dynamic mesh networks, joined by neighbouring vehicles and road infrastructure.

The Co-operative Vehicles and Road Infrastructure for Road Safety (SAFESPOT) Integrated Project, for example, aims to design an integrated system using infrastructure and vehicles as data gatherers, processors and communicators. The system is composed of different elements, including vehicles equipped with on-board co-operative systems, roadside intelligent infrastructure, and centralised traffic centres that collect and forward information received from vehicles and infrastructure.

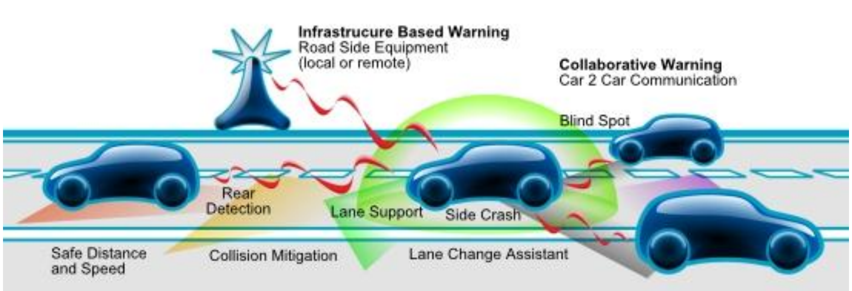


Figure 6.95: Example of the SAFESPOT co-operative system [Source: SAFESPOT Integrated Project]

Given an expected development of co-operative systems, efforts are being made to enable efficient communication between vehicles and infrastructure. Among such efforts, the definition of a data exchange common language[111] and the adoption of shared specifications for V2I and V2V communications are capable of promoting a quick roll-out of co-operative systems across Europe.

We envisage that the success of V2I and V2V systems will depend on policy developments (e.g. EU guidelines and Directives on safety, focus groups) and by the support of both associations of manufacturers[112] and original equipment manufacturers. In particular, market introduction and deployment of co-operative systems are envisaged to start as soon as in 2015.[113]

110 Different projects have been funded by the EC to define standards of use for co-operative systems. Projects include: COOPERS (Co-operative Systems for Intelligent Road Safety), CVIS (Co-operative Vehicle-Infrastructure Systems) and SAFESPOT.

111 E.g. DATEX II, which is a common data exchange language aimed to simplify the integration of third-party equipment.

112 E.g. the European Automobile Manufacturers’ Association (ACEA)

113 European Commission (2010), *ICT Research: European Commission supports ‘talking’ cars for safer and smarter mobility in Europe*. Available at http://europa.eu/rapid/press-release_IP-10-353_en.htm

Overall, we envisage spectrum usage demand to increase starting from the medium term, and to further grow in the long term, when V2I and V2V propositions will be rolled out on a multitude of vehicles and spread across different geographical regions.

Technology trend	Short term	Medium term	Long term
Integration vehicle-infrastructure	=	+	++

Figure 6.96: Impact of the integration of vehicle-infrastructure on spectrum usage demand

► *New ITS applications*

A number of new ITS applications are expected to be developed and implemented making use of a mix of existing technologies, including radio frequency identification, mobile networks and satellite tracking.

Some applications have already experienced a wide take-up; some others are still developing. We expect some trends to grow further:

- payment systems supported by in-vehicle transponders (e.g. pay-as-you-drive services, which allow to automate monetary transactions on the go)[114]
- new lease concepts (e.g. some solutions exist that allow customers to use a car and park it on the roadside at destination, paying for the actual time the car is used)
- fleet management solutions, supporting rental and transportation companies in the provision of improved customer service and maintenance level to their vehicles
- vehicle black boxes, installed by insurance companies to keep track of vehicle incidents (e.g. identification liabilities in case of accidents, vehicle tracking, driving style assessment).

Overall, we understand that innovative ITS applications will proliferate pushed by the private sector. For the next few years, we expect new applications to be effectively rolled out, and this will generate additional demand for the usage of spectrum.

Technology trend	Short term	Medium term	Long term
New ITS applications	=	+	+

Figure 6.97: Impact of new ITS applications on spectrum usage demand

6.7 Meteorology (MET)

For meteorology, the availability of spectrum is critical for weather forecasting and other related applications such as climate monitoring. One of the main uses of spectrum is for meteorological radars, which are employed to detect precipitation and patterns of variations in wind profiles. Spectrum is also used for satellite networks, such as the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), which are able to monitor Europe-wide or global weather patterns. Because radars are such an important application for meteorology, most of the spectrum bands used for meteorology are required due to their physical properties, such as the wavelengths being suitable for back-scattering off rain showers.

114 Such as road and parking toll electronic solutions.

Any technological developments are therefore likely to focus on increasing the performance of the bands that are already being used for meteorology, in order to improve the accuracy of weather forecasts. It seems unlikely that there will be significant demand for new spectrum for meteorology over the next ten years.

Figure 6.98: Summary of the main drivers of spectrum demand for meteorology and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

Meteorology	Short term	Medium term	Long term
Global Observing Systems (GOS)	=	=	=
World Meteorological Organization Integrated Global Observing System (WIGOS)	=	=	=
Harmonisation	=	=	=
OVERALL ASSESSMENT	**=**	**=**	**=**

GOS

The GOS provides high-quality, standardised observations of the atmosphere and ocean surface from all parts of the globe and from outer space. As shown in Figure 6.99, the GOS comprises observing stations located on land, at sea, on aircraft and on meteorological satellites.

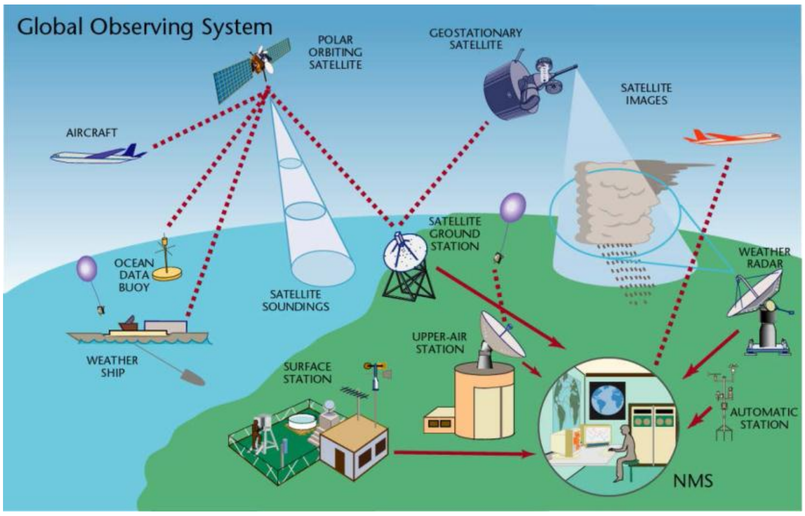


Figure 6.99: Illustration of the WMO GOS [Source: WMO, 2013]

The following table includes a list of the main GOS components.

Figure 6.100: GOS components [Source: WMO]

GOS observation components	
Surface observation	11 000 stations. Data from these stations is exchanged globally in real time
Upper air observing	1300 upper-air stations around the world representing about 800 000 lunches per annum. In ocean areas, radiosonde observations are taken by 15 ships
Marine observations	4000 observing ships. About 1000 of them report observations every day. Operational drifting buoy programme comprises about 1200 drifting buoys providing over 27 000 sea surface temperature and surface air pressure reports per day
Weather and wind profiling radars	Radar weather: Sweden 12, Spain 15, the UK 16, Germany 16, Italy 22, France 24, Poland 8 (around 160 in Europe) Wind profile about 30 in Europe
Observations from aircraft	3000 aircraft – the amount of data from aircraft has increased dramatically from 78 000 observations per day in 2000 to more than 300 000 observations per day in 2012 (i.e. 284% growth in 12 years)
Observations from satellites	The environmental and meteorological space-based Global Observing System includes constellations of operational geostationary and low Earth orbit (near-polar-orbiting) observation satellites

There are other WMO programmes that include additional observing systems such as:

- global atmosphere watch: includes more than 20 observatories and over 300 regional stations
- global climate observing systems
- hydrology and water resources programme.

In the next ten years we do not expect any incremental demand for spectrum usage for GOS.

Technology trend	Short term	Medium term	Long term
GOS	=	=	=

Figure 6.101: Impact of GOS on spectrum usage demand

WIGOS

WIGOS is an integrated, comprehensive and co-ordinated system which comprises the present WMO GOS, in particular the in-situ and space-based components of the GOS, the Global Atmosphere Watch (GAW), the Global Cryosphere Watch (GCW), and the World Hydrological Cycle Observing System (WHYCOS).

WIGOS is not in itself a new observing system, but a new framework to enable the existing observing systems to provide the data required for delivery of services across WMO's 12 application areas, and for all regions of the world, more efficiently and effectively. However, we do not expect that this will result in additional spectrum usage demand.

Technology trend	Short term	Medium term	Long term
WIGOS	=	=	=

Figure 6.102: Impact of WIGOS on spectrum usage demand

Harmonisation

A large amount of spectrum used by the Met Office and the scientific community is harmonised across Europe, or worldwide. One of the most important factors driving harmonisation is the ever-increasing reliance on satellite observation; however, we do not expect that this will result in higher spectrum usage demand.

Technology trend	Short term	Medium term	Long term
Harmonisation	=	=	=

Figure 6.103: Impact of harmonisation on spectrum usage demand

6.8 Private mobile radio / public access mobile radio (PMR / PAMR)

PMR includes not only the underlying radio network of base stations, but also the handheld, console or mobile radio devices which require the use of licensed spectrum. This category is closely linked to the PPDR category (see Section 6.10 below), as many PPDR communications systems involve applications of PMR/PAMR technologies.

PMR is also closely linked to usage for utilities and transportation. In the case of utilities, as well as existing use there are new applications of smart grid and smart metering. In transportation, PMR is a vital tool for railways, among other modes, and GSM-R uses dedicated spectrum at 800 MHz. Both these two user communities will be considered under the PMR heading, as well as general PMR, which can also be referred to as business radio.

We have classified the demand for new spectrum in PMR and PAMR in the three categories shown in the table below. Overall, there is an increased demand for spectrum for PMR/PAMR services, principally for smart grids.

Figure 6.104: PMR/PAMR categories and impact on spectrum usage demand [Source: Analysys Mason, 2013]

	Short term	Medium term	Long term
General PMR/PAMR	=	=	=/+
Smart grid and smart metering	=/+	+	+
ECTS and GSM-R replacement	=	=	=
OVERALL ASSESSMENT	**=/+**	**+**	**+**

6.8.1 General PMR / PAMR (business radio)

Overall, there is a very modest demand for new spectrum in the PMR/PAMR sector, evidenced by the growth figures for equipment, and backed up from suppliers that are seeing healthy sales. The demand will mainly depend of the demand drivers listed in the following table.

Figure 6.105: Summary of the main drivers of spectrum demand for PMR/PAMR and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

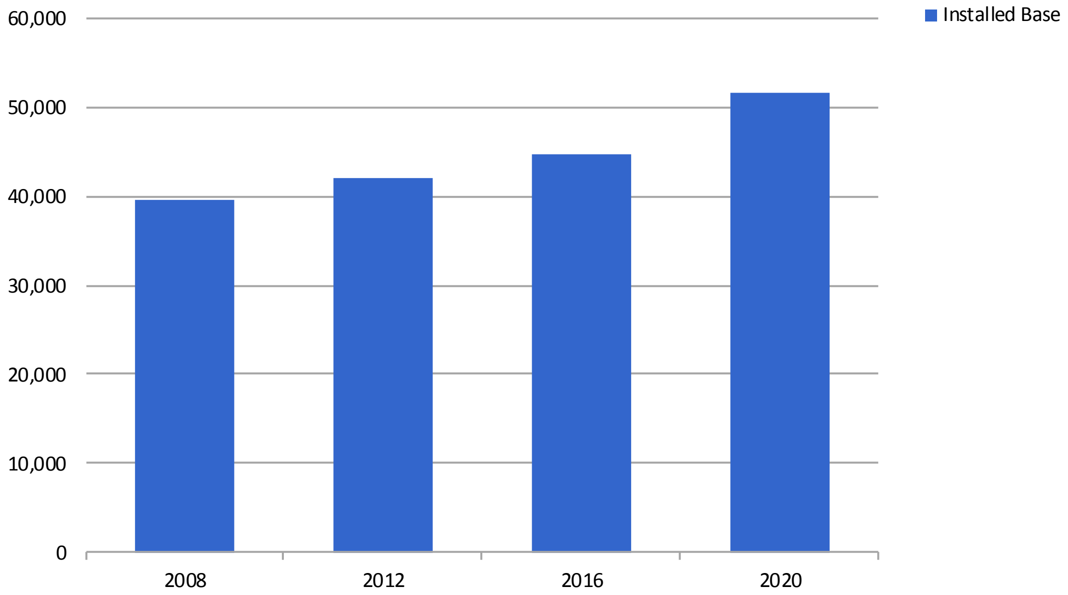
	Short term	Medium term	Long term
Growth in PMR (business radio) sales	=	=/+	+
Digital replacement of analogue communications systems	=	=	-
Level of adoption of technology advances	=	=	=
Demand for data-rich applications	=	=	=
Potential to switch to alternative services	=/-	=/-	=/-
OVERALL ASSESSMENT	**=**	**=**	**=/+**

Growth in PMR (business radio) sales

PMR covers a wide range of applications. As well as PPDR, utilities and railways, it covers areas such as airports, buses, trams, ports, construction, local government, manufacturing healthcare, retail, hospitality and manufacturing. There are links to other sectors; for example, PMSE uses PMR to support communications between field units and the broadcasting studio, which will increase the demand for spectrum. PMR contributes significantly to society and has a large societal value: estimates for the UK in 2007 were GBP1–2 billion.[115]

Growth in PMR equipment worldwide is forecast to increase by 25% between 2012 and 2020. It is estimated that the installed base of active radios in the EU is some 33% of the global base.

Figure 6.106: Installed base of active radios worldwide (thousand) [Source: IMS Research, 2013]



115 Source: FCS Report.

Overall, use of PAMR systems has not increased in recent years, and in some countries it has even declined. There are some systems but with limited usage, and many users have moved already to commercial networks.

Technology trend	Short term	Medium term	Long term
Growth in PMR (business radio) sales	=	=/+	+

Figure 6.107: Impact of the growth in PMR (business radio) sales on spectrum usage demand [Source: Analysys Mason, 2013]

Digital replacement of analogue communications systems

Current spectrum efficiency for analogue PMR is one channel in 12.5 kHz, while new digital technologies provide a two-fold increase to 6.25 kHz equivalent. The market share of digital is estimated at 30–40%,[116] and sales of digital radios are estimated at 70%, thus increasing the efficiency of radios in the market. Notwithstanding this, experience with digital mobile radio (DMR) (one of the new technologies standardised by ETSI) suggests that users use the extra capacity to improve operations (perhaps for data alongside voice), so the two-fold efficiency does not materialise in reality.

In time, as more systems move to digital, and a larger number of users migrate to digital, the benefit is expected to materialise.

Technology trend	Short term	Medium term	Long term
Digital replacement of analogue communications systems	=	=	-

Figure 6.108: Impact of the digital replacement of analogue communications systems on spectrum usage demand

Level of adoption of technology advances

There is no pressure on users to replace equipment and move to more spectrum-efficient technology. We have seen no evidence regulators will force uses, unlike in the USA, where the 12.5 kHz narrowbanding mandate from the Federal Communications Commission (FCC) is now in force. Instead, replacement happens when old equipment fails, or does not meet the user’s business needs, which will be a gradual process.

There are no developing technology standards to achieve higher spectrum efficiency.

Technology trend	Short term	Medium term	Long term
Level of adoption of technology advances	=	=	=

Figure 6.109: Impact of the level of adoption of technology advances on spectrum usage demand

116 Ofcom (2011), *Business radio interest group*. Available at http://stakeholders.ofcom.org.uk/binaries/spectrum/spectrum-industry-groups/business-radio-interest-meetings/meeting-20-october-2011/Ofcom_slides_for_BRIG_20_Oc1.pdf

Demand for data-rich applications

There is a clear demand for data-rich applications in public safety (PPDR) and railways, but less so from other PMR users.

Generally, business radio users who are using data have access to efficient transmission signalling protocols which optimise the sending of data over narrow PMR channels, satisfying their immediate requirements. This will tend to be business-critical data rather than mission-critical data, which means the cost of the service has to be factored into the decision process.

There is some demand from business radio users for wide and broadband data, and this will currently be met using commercial networks. For example, the bus operator in London uses GPRS to get data from buses, since its PMR network has insufficient capacity. With such a diverse range of users of PMR, there is no clear justification for broadband dedicated spectrum for PMR.

Technology trend	Short term	Medium term	Long term
Demand for data-rich applications	=	=	=

Figure 6.110: Impact of demand for data-rich applications on spectrum usage demand

Potential to switch to alternative sources

There is a churn between PMR and commercial networks. PMR users leave PMR and move to commercial networks, due to a number of reasons:

- the cost of PMR equipment
- coverage does not meet their needs
- features such as smartphones and high data speeds are not so easily available in PMR.

At the same time, some users find that the only suitable technology for them is PMR, and so move from commercial networks to PMR. Examples include:

- a need for good reliable indoor coverage, such as a conference centre or arena
- a need for instant fast responses, such as staff in a large hotel or casino
- the costs of using a commercial network (opex) against the capex, but no opex of PMR.

Churn will tend to balance out, but with a slightly reduced demand in the medium to long term.

Technology trend	Short term	Medium term	Long term
Potential to switch to alternative services	=/-	=/-	=/-

Figure 6.111: Impact of the potential to switch to alternative services on spectrum usage demand

6.8.2 Smart grid and smart metering

Utility networks use a mixture of PMR and commercial networks, including mobile, satellite and DSL, but as part of a country's critical national infrastructure, radio communications are vital to the utility industry. They will need to provide coverage into remote areas where the utilities provide power lines and switching, and be resilient against power failure.

Figure 6.112: Summary of the main drivers of spectrum demand for smart grid and smart metering, and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

	Short term	Medium term	Long term
Energy policies, climate change and environmental regulation	=	=/+	+
+World market forces	=	=/+	=/+
Potential compression benefits from new technologies	=	=/-	-
Potential use of alternative networks	=	=	=
Demand from utilities	+	+	+
OVERALL ASSESSMENT	**=/+**	**=/+**	**+**

The inputs received from stakeholders and our own research indicate that there is a strong demand for spectrum for smart grid applications, which in many cases can only be met by PMR-type systems. There is demand also for smart metering, but it is less clear that this would be PMR spectrum. Instead, this could use commercial or SRD spectrum, or a mixture of technologies in different locations.

Energy policies, climate change and environmental regulation

EU policy and directives have set climate and energy targets for 2020, known as the '20-20-20' targets. These are:

- 20% reduction in EU greenhouse gas emissions from 1990 levels
- raising the share of EU energy consumption produced from renewable resources to 20%
- 20% improvement in energy efficiency across the EU.

These targets affect all utilities. For example, environmental regulation and climate change (flood control) has an impact on water utilities, thus increasing the need for more monitoring and control.

For the power utilities, the directives have a direct impact, and lead to smart grid and smart metering:

- utilities need to have more renewable energy sources, which will be distributed, and must be controlled: this is *smart grid*
- there must also be more control on matching demand for power to generation capability, and understanding of consumer requirements: this is *smart metering*.

Smart metering may be carried over a wide variety of bearers, which could be commercial networks, wireless exempt or lightly licenced mesh networks, or long-range PMR networks. A solution may use different technologies in different locations to achieve a near 100% coverage of indoor smart meters.

For smart grid, in some cases commercial mobile or satellite may be used, but utility monitoring and control points cannot be located to suit terrestrial cellular coverage, and the availability may not be acceptable, leaving dedicated spectrum on private radio networks as the preferred solution.

Technology trend	Short term	Medium term	Long term
Energy policies, climate change and environmental regulation	=	=/+	+

Figure 6.113: Impact of energy policies, climate change and environmental regulation on spectrum usage demand

World market forces

Energy costs are increasing, and resources are reducing. Gas is increasingly used for low carbon power generation, and the world market drives gas costs.

Consumers are more demanding, and more services rely on electricity than ever before, such that extended power outages are unacceptable and costly. It is estimated that the cost of all power outages in the USA is USD104–164billion per annum.

Cyber security of utility networks is increasing in importance. Although smart metering may not be mission-critical, there are messages in the protocol which can disable a user's power supply, and the potential for fraud, so security and encryption are paramount.

Utilities are commercial businesses, and have to satisfy their shareholders while meeting increasing policy and regulatory requirements. They have to be more efficient, and match supply more closely with demand, with less spare capacity, and provide higher availability; this requires more complex communications, some of which has to be wireless and PMR.

Technology trend	Short term	Medium term	Long term
World market forces	=	=/+	=/+

Figure 6.114: Impact of world market forces on spectrum usage demand

Potential compression benefits from new technologies

Utilities use analogue PMR equipment. Changing to digital for their voice networks will give them some efficiency savings.

Existing supervisory, control and data acquisition (SCADA) and telemetry networks are already highly optimised to use narrow data channels (often 9.6kbit/s), so any benefits from improved technology are likely to be low.

Also, home area networks (HANs) using technologies such as Zigbee are new applications, so will have an increased spectrum need, as opposed to providing compression benefits.

There are therefore very limited opportunities for communications to benefit from new technologies in the short term, but could potentially materialise in the long term.

Technology trend	Short term	Medium term	Long term
Potential compression benefits from new technologies	=	=/-	-

Figure 6.115: Potential compression benefits from new technologies

Potential use of alternative networks

Commercial networks are used by utilities; however, the criticality of smart grid makes them generally unsuitable for this application. In a large power outage, the commercial sites will fail quickly, when communications are required to restore the network.

Smart metering on the other hand is an application where non PMR-type communications can be used, although quality of service and security might be an issue. Potential alternative networks include:

- commercial networks (GPRS or 3G)
- mesh networks (using lightly licenced or licence-exempt spectrum (such as 870–876 MHz))
- power line communications (which are outside the scope of this study).

Since the choice of bearers for smart metering is driven by commercial drivers as much as by technical solutions, there is no quantifiable impact on spectrum usage from alternative networks.

Technology trend	Short term	Medium term	Long term
Potential use of alternative networks	=	=	=

Figure 6.116: Impact of the potential use of alternative networks on spectrum usage demand

Demand identified by utilities

The utilities' functional requirements cover protection, control, SCADA, voice, CCTV, management and metering.

During discussions with the European Utilities Telecom Council (EUTC), the following spectrum requirements were identified:

- VHF spectrum (50–200 MHz) for resilient voice communications and distribution automation for rural and remote areas [2×1 MHz] – not relevant to this study
- UHF spectrum (450–470 MHz) for SCADA and automation [2×2.5MHz]
- lightly regulated or deregulated shared spectrum for smart meters and smart grid [870–876 MHz]

- L-band region (1500 MHz) for more data-intensive smart grid, security and point-to-multipoint applications [10 MHz]
- public microwave and satellite bands (1.5–58 GHz) for access to utilities' core fibre network or strategic resilient backhaul.

Submissions from ESB (Ireland) and Alliander (the Netherlands) support these requirements. ESB suggests 2×1.5 MHz UHF + 10 MHz sub 1 GHz, while Alliander suggest 2×3 MHz in 450–470 MHz. In particular, they are looking to deploying CDMA in this band.

The above represents a significant demand requirement for spectrum for utilities.

Technology trend	Short term	Medium term	Long term
Demand from utilities	+	+	+

Figure 6.117: Impact of demand from utilities on spectrum usage demand

6.8.3 ETCS, GSM-R and future railways technologies

Roll-out of the European Train Control System (ETCS)

The ETCS is the new standard of rail traffic management which is gradually being rolled out across Europe. It is a signalling, control and train protection system which is to be deployed across countries to ensure cross-border compatibility with systems currently used by European railways.

The system makes use of both passive (such as Eurobalises) and active elements (such as GSM-R equipment). Passive elements serve signalling purposes, providing trains with positioning and safety-relevant information. Active elements are used for bi-directional communications with data-gathering centres, which receive data mainly on train speed and positioning, and reply with instructions regarding authorisation to enter the upcoming track segment and the relative maximum speed.

For what concerns passive equipment, the 26.35–27.5 MHz bands are currently employed by railway applications, with Eurobalise equipment operating on 27.095 MHz. Further and wide deployment of passive equipment onto European rail networks is envisaged. Nevertheless, the impact of such a deployment on spectrum usage demand may be null.

For what concerns active equipment, ETCS is a relatively low-bandwidth application, and its further deployment is expected to have a modest impact on spectrum usage.

Technology trend	Short term	Medium term	Long term
Roll-out of ETCS	=	=	=

Figure 6.118: Impact of the roll-out of ETCS on spectrum usage demand

Replacement of GSM-R

Use of spectrum designated to GSM-R is currently at 10–20%. The European Railway Agency (ERA) claims that it is important to have its own uncongested spectrum for safety of life/critical infrastructure reasons. GSM-R currently covers ~60 000km of track, which will grow to 160 000km by 2016.[117] GSM-R development is projected to arrive at an end by 2020. The ETCS currently uses circuit-switched links over GSM-R, but a move to packet-switched transmission is envisaged by 2020. This would lead to higher spectrum efficiency. LTE appears to be a likely candidate to replace GSM-R, after proving it can reliably handle both voice and data.

Overall, further development of GSM-R is not expected to generate additional spectrum usage. However, during the transition from GSM-R to a future solution, additional spectrum on a temporary basis may be required, to facilitate parallel operation of new and old systems.

Technology trend	Short term	Medium term	Long term
Replacement of GSM-R	=	=	+

Figure 6.119: Impact of the replacement of GSM-R on spectrum usage demand

6.9 Programme making and special events (PMSE)

PMSE covers a wide variety of organisations involved in social, cultural and entertainment events, and individuals who use spectrum for an equally wide variety of reasons. They range from audio users, such as professional theatre companies, film production companies and community users (often churches and schools), to video users such as broadcasters and special events organisers.

PMSE is used across a large number of spectrum bands, from 47.55 MHz through to 48.4 GHz. PMSE use of interleaved spectrum primarily consists of wireless microphones and in-ear monitors, although there is some use of other equipment such as talkback and other audio links.

The PMSE industry estimates that there are between 4 million and 5 million users in Europe. PMSE is used by both non-broadcast and broadcast applications. The split of PMSE usage between broadcast and non-broadcast applications is as follows:

- *70% non-broadcast applications* – typically includes actors ‘on tour’, audio and video distribution systems, business installations, church installations, conference installations, entertainment production, industry trade shows, content to be distributed on the Internet, movie production, music groups ‘on tour’, musical production, studio production, theatre installations, theatres ‘on tour’, universities and schools.

- *30% broadcast applications*[118] – typically includes TV production, radio production, sport production, news gathering and national events.

117 International Union of Railways – Interferences into GSM-R due to public mobile radio networks (23 March 2011)

118 Draft CEPT Report 32.

Although the use of some PMSE spectrum is concentrated among a small number of users, a significant portion of use is fragmented. For example, in the UK:

- 50 users account for 50% of all spectrum usage; the BBC alone accounts for 13%
- approximately 64 000 individual PMSE frequency assignments are made to around 1 300 different organisations and individuals each year.

Overall, as shown in Figure 6.120 below, future demand for spectrum for PMSE will mainly depend on:

- the type and number of events
- the type of equipment and growth
- increase in the amount of equipment per event
- adoption of HD and 3D cameras.

Figure 6.120: Summary of spectrum demand drivers for PMSE and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

PMSE	Short term	Medium term	Long term
Type and number of events	+	+	+
Type of equipment and growth	+	+	+
Increase in the amount of equipment per event	+	+	++
Adoption of HD and 3D cameras	+	+	++
OVERALL ASSESSMENT	**+**	**+**	**+/++**

Type and number of events

The fields where PMSE applications are used are quite broad, encompassing theatres, rock and pop events, touring shows, studio production, news gathering for TV/radio/Internet, sound broadcast, casual sport events, special events, places of worship, film and advert production, corporate events, social use, conference and political events, etc.

The demand for spectrum for PMSE applications varies depending on the number of events covered and the particular scenario of use:

- *Hot spots with high demand:* In some areas (e.g. where there are a large number of theatres) demand for spectrum can be high at particular times of day, or as a result of other factors. For example, Figure 6.121 shows that 20 theatres lie within a 1km radius in the West End of London.

- *Hot spots where production facilities are located:* In particular areas where production facilities are located, the density and deployment of PMSE equipment is high, as is its probability of use. The usage is dependent on the work/rehearsal/performance schedule. During such phases, the probability of use is 100%, while at other times the probability of use is low.

- *Situations of low demand:* In some areas, such as where a place of worship or some corporates are located, spectrum demand is low and may vary by time of day or other factors. Figure 6.122 below provides an example of PMSE demand in some areas of the Netherlands.
- *Exceptional demand in rural areas:* Spectrum requirements can sometimes arise in areas where no PMSE applications are normally deployed (such as rural areas), as a result of unexpected events, natural disasters or war situations. It is not possible to plan for PMSE use in these scenarios, or the amount of spectrum required.
- *Exceptional demand in urban areas:* Some of the events covered by outside broadcasts are highly unusual in terms of the attention they attract, their size, large geographical scale, etc. Some examples of such special events are:
  - — major large-scale sporting events such as the Tour de France, London Marathon, Wimbledon tennis championships, the Olympic Games, the football World Cup, etc.
  - — major national celebrations, such as royal weddings and funerals, papal visits, etc.
  - — major multinational/EU events such as the G8 summit/ G20 summit.

As explained above, usage varies by geographical region and by type of user. For example, in the UK 50% of assignment days occur in only 4% of locations.[119] London's West End theatre industry is a good example of this, since 20 of the largest theatres are located within a 1km radius, as shown in Figure 6.121 below.

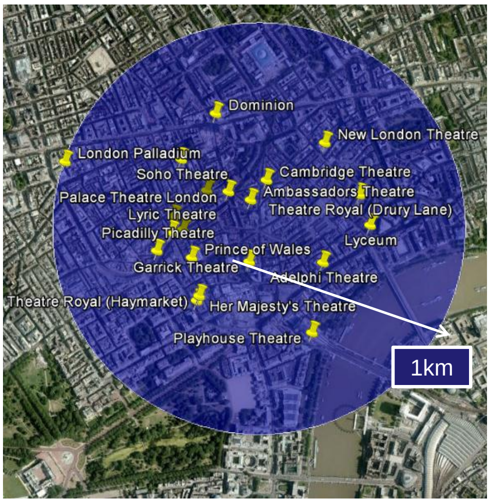


Figure 6.121: Theatres located within a 1km radius, situated in the West End of London

The number and types of events where PMSE equipment is used have been increasing in recent years. In London, for example, the number of theatre performances that involved use of PMSE equipment increased by 4% between 2009 and 2010, from 17 900 to 18 600. In 2011, it is estimated that in total these theatres used around 600 wireless microphones, which is equal to an overall spectrum demand of approximately 940 MHz.

119 Source: Quotient research.

The table below presents the amount of equipment used and associated spectrum requirements in the Netherlands, according to population density. Although some of these types of areas are not considered as PMSE hot spots, the requirement for PMSE applications is still significant.

Figure 6.122: Amount of PMSE equipment used in the Netherlands, and associated spectrum requirements [Source: Dutchview]

PMSE	No. of systems	Requirements
Village countryside (<500 people in 1km^2)	12	>12 MHz
Village countryside (<500 people in 1km^2 with a small event)	38	>40 MHz
Town (500–1000 people in 1km^2)	56	>80 MHz
City (1000–2500 people in 1km^2)	>102	>100 MHz
Capital city (>2500 people in 1km^2)	>>200	>>130 MHz

The fields where PMSE applications are used are quite broad, and they are increasing. As a result, we expect a positive increase in spectrum demand in the next ten years.

Technology trend	Short term	Medium term	Long term
Type and number of events	+	+	+

Figure 6.123: Impact of type and number of PMSE events

Type of equipment and growth

Although a wide range of PMSE equipment makes use of spectrum, the equipment can be grouped into seven main categories.

- *Wireless microphones* – wireless microphones used by a wide range of applications, including TV production, theatre production, outside broadcasts and concerts. Wireless microphones can be hand held by presenters/performers, or worn on the body. They operate at low power to transmit audio to a nearby receiver and most are used indoors (although outdoor use is also possible). With some limited exceptions, wireless microphones generally operate with a maximum effective radiated power (ERP) of 50mW. To enable high-quality sound, they operate in a bandwidth of 200 kHz.

- *Talkback* – voice communications used to relay instructions between individuals involved in the production of a programme or event. Talkback can provide one- or two-way communication. An example includes an outside broadcast unit communicating with a studio. There are several different types of talkback, with low to medium output power. They are mainly used indoors. Talkback devices typically operate in 12.5 kHz, although they often require higher power levels– often as high as 1W ERP for hand-held devices and up to 5mW for talkback base stations.

- *In-ear monitors* – low power, wireless audio links that provide one-way communication from production staff to presenters/performers.

- *Data links* – telemetry point-to-point links used to control equipment used in programme making and special events. A good example of this use would be the remote control of a wireless camera.

- *Audio links* – fixed, mobile, portable or airborne point-to-point links used to carry audio signals between locations. The distances over which audio is transmitted can vary from very short (e.g. within a studio) to much further (e.g. from an outside broadcast unit to a studio).
- *Wireless cameras* – cameras used in conjunction with a wireless link, which transmit video and audio to a receiver. The receiver could be located, for example, on a link vehicle, on an aerial midpoint (such as a helicopter or blimp), on a rooftop or mounted within a stadium. The transmission bandwidth of modern digital camera systems is typically in the range 8 to 10 MHz (or, in the case of analogue systems, up to 20 MHz). The total amount of spectrum required for wireless cameras at any time depends on the size of the event. For example, an average sporting event requires about 48 MHz of spectrum, while larger events (such as the Tour of Ireland cycle race) require closer to double this amount. Occasional high-profile international events (such as the 2006 Ryder Cup) can require more than 200 MHz of spectrum, designated to a mix of broadcast and CCTV camera links.
- *Video links* – fixed, mobile, portable or airborne point-to-point links used to carry video between locations. The transmission distances can vary from very short (within a studio) to much longer (from an outside broadcast unit to a studio).

PMSE makes extensive use of **wireless microphones**. The number of wireless microphones deployed in the EU has only been roughly estimated. In a survey carried out among a small group of professional audio distributors in 2010, a Dutch interest group[120] came up with a figure of 250 000 systems (transmitter and receiver) sold in the Netherlands in the last decade. If this number is extrapolated over the total number of EU inhabitants, it can be concluded that the total number of channels deployed is around 10 million, with about 8 million daily users. To date, adoption of digital wireless microphones has been limited, although it is expected to increase over the next decade.

As shown in Figure 6.124 below, wireless microphones in the UK are expected to grow by between 10% and 29% per annum in the short term.

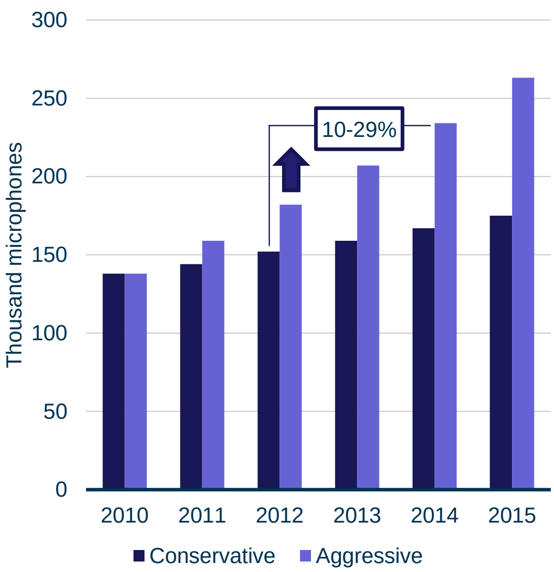


Figure 6.124: Forecast of number of wireless microphones in the UK, 2010–2015 [Ægis Systems Limited]

[120] PMSE.nl

We also expect an increase in the number of **in-ear monitors**, for three main reasons:

- the price is going down
- musical shows are moving towards providing one in-ear monitor for each artist
- 'in vision' presenters prefer an in-ear monitor rather than a walkie-talkie for their cue feed. Many presenters use 'open' talkback, and the bandwidth of an in-ear monitor (approximately 200 kHz) is easier to listen to for long periods than a walkie-talkie (12.5 kHz).[121]

Because we expect an increase in the amount of equipment used by PMSE users, we therefore expect a positive increase in spectrum demand in the next ten years.

Technology trend	Short term	Medium term	Long term
Type of equipment and growth	+	+	=/+

Figure 6.125: Impact of type of PMSE equipment and growth

Increase in the amount of equipment per event

Demand for PMSE spectrum varies significantly by country, programme maker and event. Broadcasting programmes and the events that are covered are becoming technically more complex, and so require more-advanced equipment such as wireless HD cameras, telemetry devices across a wider range of sports, further development of graphic capabilities, continuous 360-degree viewing, 3D TV and ultra-HD, and fusion of games with sports broadcasting.

Broadcasting programmes and events that require PMSE spectrum are becoming increasingly complex and technically demanding, thus requiring more equipment on the site, as shown below.

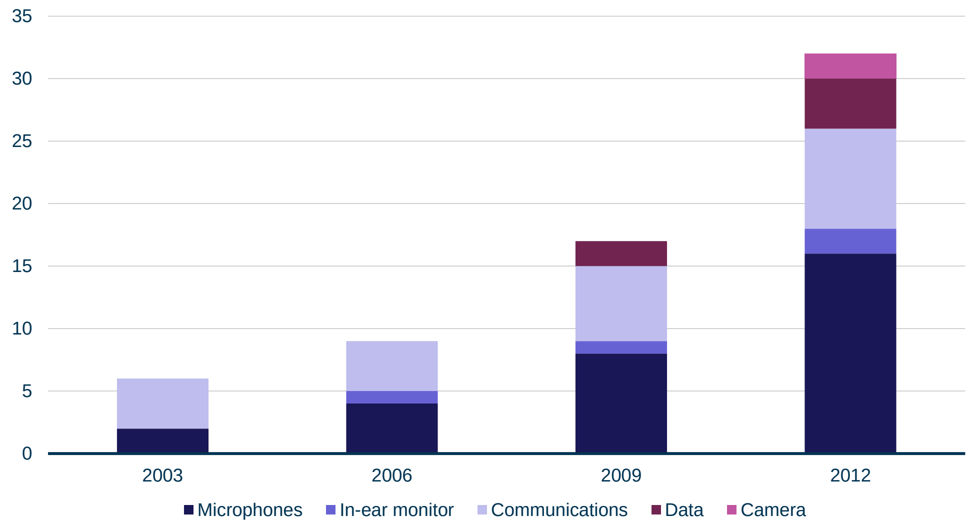
Figure 6.126: Band usage by category of equipment [Source: ECC SAP/SAB Lisbon, February 2002]

	Equipment	Year	Electronic news gathering	Outside broadcasting, e.g football match	Outside broadcasting, major annual events
Video	Wireless camera	2002	(2…5) × 20MHz ch	(1…5) × 20MHz ch	(5…10) × 20MHz ch
		2012 F	(10…15) × 10MHz ch	(8…10) × 10MHz ch	(10…20) × 10MHz ch
	Temporary point to point links	2002	(2…5) × 20/28MHz	(1…2) × 20/28MHz	(2…5) × 20/28MHz
		2012 F	(10…15) × 8/10MHz	(3…5) × 14/28MHz	(10…20) × 14/28MHz
Audio	In-ear monitors	2002	10…15 ch	1…5 ch	20…80 ch
		2012 F	15...30 ch	5…10 ch	20...80 ch
	Portable audio links	2002	3…5 ch	1…5 ch	10…20 ch
		2012 F	5…10 ch	5…10 ch	10…20 ch
	Mobile audio links	2002	3…5 ch	3…5 ch	5…10 ch
		2012 F	5…10 ch	5…10 ch	10…20 ch

121 Source: Charter Broadcast UK.

Broadcasters are also making increasing use of PMSE equipment. For example, as shown in Figure 6.127, for the same TV show DutchView used 32 units of equipment in 2012, up from 17 units in 2009 (an 88% increase).

Figure 6.127: Example of PMSE equipment growth in a TV show [Source: Dutchview, 2013]



The main reason for the sharp growth in PMSE equipment used by broadcasters is the fact that wireless equipment offers freedom of movement to users. This is not the only reason, however. For example, the nature of studio use has changed:

- A range of programmes such as “Big Brother” now have permanent new studios, and there has been an increase in the number of programmes produced within traditional studios, to service the demands of the multimedia industry.
- Many public broadcasters have now sold off their studio complexes to private organisations. As a result, these studios are not only used by the public broadcaster but they are also used intensively by other programme-making companies.
- The complex frequency environment of these sites requires detailed frequency planning to ensure that no interference is generated between the devices on site.

At the TV studios in Hilversum, the Netherlands, Dutchview estimates a daily use of 225 systems in around one square kilometre, which requires more than 130 MHz. During peak times the number of systems increase to 358, and the spectrum requirement is more than 200 MHz.

In hot-spot scenarios with high demand, such as London’s West End, spectrum requirements are high and they are increasing due to higher-quality production. On average a musical show in London uses around 40 wireless microphones and other PMSE equipment which requires around 40–50 MHz.

Non-broadcaster users have also increased their use of PMSE equipment. For example, in the case of the Tour de France, the demand for frequencies for wireless microphones has risen consistently in recent years (365 in 2007, 398 in 2008, 430 in 2009, 456 in 2010 and 463 in 2011). Meanwhile, the number of frequencies required by the Tour de France for other uses has increased slightly in recent years (287 in 2009, 319 in 2010 and 327 in 2011).

Exceptional demand in urban areas to cover some sport events has also increased significantly. In the case of the Olympic Games, the licensing situation and PMSE spectrum use changed significantly between Athens 2006 and London 2012:

Figure 6.128: Licensing situation and PMSE spectrum for the Olympic Games, Athens 2004 vs London 2012[Source: Ofcom and ECC Report]

	MHz of spectrum used		
Device type	**Athens 2004**	**London 2012**	**Growth**
Wireless microphones	527	1958	4×
Wireless camera	44	631	14×
Talkback	423	3037	7×
In-ear monitor	71	1468	21×

Figure 6.129 below provides a sample of spectrum requirements for PMSE applications at some major events in Germany.

Figure 6.129: Spectrum requirements of PMSE applications at major events in Germany [Source: BNETZA, EC Radio Spectrum Policy Group, 2013]

Event	Date	Links	Bandwidth
12th IAAF World Athletics Championships	15–23 August 2009	42 wireless cameras/video links	619 MHz
Celebration of the 20th anniversary of the fall of the Berlin wall	9 November 2009	38 wireless cameras/video links	350 MHz
Berlin state elections	18 September 2011	17 wireless cameras/video links	162 MHz
German presidential election in the Reichstag building	18 March 2012	17wireless cameras/video links, 198 microphones/audio links and 97 service links (voice/telemetry)	164 MHz + 37.71 MHz + 1945 MHz

As with most other events and content production, PMSE use at the Eurovision Song contest has also risen over time, as shown in Figure 6.130.

Figure 6.130: PMSE use at the Eurovision Song Contest [Source: Professional Lighting & Sound Association, August 2012]

Year	Location	Wireless microphone use	In-ear monitor (IEM) use
1956	Lugano, Switzerland	Wired microphones only	-
1980	The Hague, Netherlands	4–24 ch wireless mics	-
1998	Birmingham, UK	40 ch wireless mics	2 ch IEM
2001	Copenhagen, Denmark	48 ch wireless mics	16 ch IEM
2004	Istanbul, Turkey	54 ch wireless mics	16 ch IEM
2007	Helsinki, Finland	56 ch wireless mics	16 ch IEM
2010	Oslo, Norway	72 ch wireless mics	32 ch IEM
2012	Baku, Azerbaijan	104 ch wireless mics	80 ch IEM

We expect the amount of equipment used at each PMSE event to continue to increase as it has done in the past, and so we expect a positive increase in spectrum demand in the next ten years.

Technology trend	Short term	Medium term	Long term
Adoption of equipment per event	+	+	++

Figure 6.131: Impact of increase in amount of PMSE equipment per event

Adoption of HD and 3D cameras

Demand for wireless cameras and video links will increase through the introduction of HD services and increasing demand for higher-quality broadcast content, which requires multiple camera angles and mobility, particularly for news gathering. Most wireless cameras now use HD technology, and some broadcasters (e.g. BSkyB) now produce sports events in 3D, while we understand that BBC Sports is conducting 3D trials.

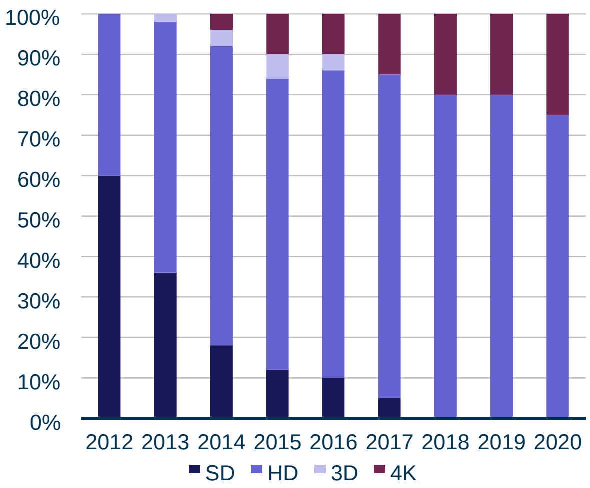


Figure 6.132: Forecast of broadcast quality distribution [Source: PMSE Netherlands]

HD audio is capable of delivering 192 kHz/32-bit audio quality. Strong take-up of HD and 3D cameras would result in a step-increase in spectrum demand in the next ten years.

Technology trend	Short term	Medium term	Long term
Adoption of HD and 3D cameras	+	+	++

Figure 6.133: Impact of the take-up of HD and 3D cameras

6.10 Public protection, disaster relief (PPDR)

PPDR mobile communications have generally been based on PMR technologies, such as those used in the TETRA or Tetrapol networks which are used by the majority of police organisations in Europe. Many of these networks use spectrum in the 380–400 MHz band, and since this is very close to the lower limit of the frequencies covered by this study (400 MHz) they will also be included in our considerations. PPDR applications also make use of other services and bands, such as satellite communications for operations in remote areas, or the increasing trend of integrating GNSS receivers into PPDR communications equipment to pass back location information to the control room.

In the following subsections we assess the impact of PPDR services on future demand for spectrum in terms of the following factors:

- increasing demand for data-rich applications – there is a growing need for high-speed data services; this need could be met through a new mobile broadband network (which may be a service from a commercial operator), but since a growing proportion of these applications will be mission-critical, it is more likely to be met through a dedicated PPDR network
- growth in communications for PPDR purposes, in response to increases in terrorism and new forms of crime
- the potential for PPDR services to make use of commercial services and networks
- the adoption of new technologies.

Figure 6.134: Summary of spectrum demand drivers for PPDR and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

PPDR	Short term	Medium term	Long term
Increasing demand for data-rich applications	=	+	++
Growth in PPDR communications	=	+	+
Use of commercial services	=	=	=
Adoption of new technologies	=	=	=
OVERALL ASSESSMENT	**=**	**+**	**++**

Demand for data-rich applications

There is an increasing trend for PPDR applications to use commercial mobile services for data communications, with devices such as Blackberries and applications such as video-over-3G and despatching over GPRS. At present, these services are generally used only for administrative or non-critical communications, and the PPDR organisation has the PMR-based network to use should there be problems with the commercial network. However, trends will change in future and there is a clearly recognised need to support more data-rich applications for PPDR organisations. The need for a broadband data network dedicated to mission-critical applications is under consideration across Europe; and such a network is already being implemented in the USA.

Furthermore, it could also be argued that there is a greater need for interoperability between different PPDR networks, as well as between PPDR networks and commercial networks. Interoperability on a global scale would also be advantageous for services such as cross-border and international rescue operations. Equally, harmonisation of spectrum on at least a regional basis is seen as important, to achieve economies of scale in what is a small but crucial market.

The demand for data-rich applications has originated with users, and has been captured by the Radio Communication Expert Group of the Law Enforcement Working Party (LEWP-RCEG), who have considered PPDR in its wider sense covering all user groups. The TETRA + Critical Communications Association has formed the Critical Communications Broadband Group (TCCA CCBG), which is looking at developing mobile broadband standards for critical communications, and is attended by organisations in the fields of public safety, utilities and UIC (railways). LEWP-RCEG has worked with ETSO TC TETRA WG4 on identifying the bandwidth needs for the required services, and has developed a number of scenarios in order to specify a data bandwidth requirement, which in turn has been input into CEPT Working Group FM Project Team 49, which is looking at broadband spectrum for PPDR. The working group has recently sent a draft report (ECC 199) out for consultation.[122]

This report identifies a minimum requirement of 2 × 10 MHz of spectrum for mobile broadband for PPDR. It notes that this requirement does not include voice, air-ground-air (AGA), direct mode operations (DMO) or ad-hoc networks. Voice is believed to require a further 2 × 3.2 MHz. AGA was not quantified, but an input from the Ministry of the Interior in Germany suggests a base requirement of 15 MHz with a further 7.5 MHz for localised video links. The initial conclusions of the report are summarised in Figure 6.135 below.

122 http://www.cept.org/ecc/groups/ecc/wg-fm/fm-49/page/the-public-consultation-of-the-draft-ecc-report-199-is-open

*Figure 6.135: Identified uplink and downlink bandwidth requirements [Source: ECC Draft Report 199, 2013] *The differences between 420MHz and 750MHz are due to the differing cell sizes for these frequencies: since 420MHz cells are larger, more incidents will take place within them.*

Table 1: Total uplink bandwidth requirement for BB data communications

Frequency band	Traffic assumption	Low estimate	Medium estimate
420 MHz	1 incident "cell edge" 3 incidents near cell centre and background communications	8.0 MHz	12.5 MHz
750 MHz	1 incident "cell edge" 2 incidents near centre and background communications	7.1 MHz	10.7 MHz

Table 2: Total downlink bandwidth requirement for BB data communications

Frequency band	Traffic assumptions	Low estimate	Medium estimate
420 MHz	1 incident "cell edge" 3 incidents near centre with background communications	7.6 MHz	10.5 MHz
750 MHz	1 incident "cell edge" 2 incidents near centre with background communications	6.9 MHz	9.0 MHz

ECC Report 199 does not suggest what spectrum should be used to satisfy this requirement, but Project Team 49 will be addressing this next, and feeding their input to ITU WP5A as part of the preparations for WRC-15.

Technology trend	Short term	Medium term	Long term
Data-rich applications	=	+	++

Figure 6.136: Impact of demand for data-rich applications

Growth in PPDR communications requirements

Our research indicates that increases in global terrorism and activism as well as new forms of crime will increase the workload of PPDR organisations, requiring more covert and overt communications and thereby creating a small increased demand for narrowband spectrum. This demand will particularly be for major incidents, and within border areas where coordination of PPDR activities is required.

There are some instances of TETRA Enhanced Data Service (TEDS) wideband solutions being deployed (or planned) as an interim measure, before dedicated broadband communications are available. This would require some 2 × 3 MHz of spectrum, which would have to be within the tuning range of the existing narrowband TETRA terminals. However, these deployments are limited at this stage, and are not pan-European in scope.

Technology trend	Short term	Medium term	Long term
Growth in PPDR communications	=	+	+

Figure 6.137: Impact of growth in PPDR communications

Use of commercial services

PPDR users already use commercial broadband networks alongside their existing narrowband voice and critical data networks, and will continue to do so. An example of this is the MVNO being established by ASTRID in Belgium; this will be a data-only network, and the existing TETRA network will provide fallback in the event of failure of the MVNO's network.

Technology trend	Short term	Medium term	Long term
Switch to commercial services	=	=	=

Figure 6.138: Impact of demand to switch to commercial services

Adoption of new technologies

While some PPDR users will choose to use 3G and 4G commercial networks for some purposes, at present these networks do not have the resilience and level of availability provided by dedicated PPDR networks. In the future 4G networks may be improved by MNOs to a point that they can have the resilience and availability of dedicated PPDR networks, but this will be costly, and may need to be funded by PPDR organisations. MNOs will need a business case and justification if they are to enhance their networks and many European PPDR organisations will be able to justify keeping control of their own dedicated network.

In addition, there is an issue of whether PPDR users will have sufficient access rights and control for 3G/4G networks to be effective in a major incident. Developments are taking place within 3GPP to introduce public safety voice and unit-to-unit features into evolving LTE standards. It is anticipated that mission-critical PPDR services will evolve in four stages, as illustrated in Figure 6.139 below: (i) *Upgrade* of the existing networks; (ii) *Learn* – where PPDR organisations will learn to use broadband data applications; (iii) *Build* – involving the roll-out of dedicated broadband networks; and finally (iv) *Migrate* – during which PPDR services will be fully migrated to mission-critical data networks.

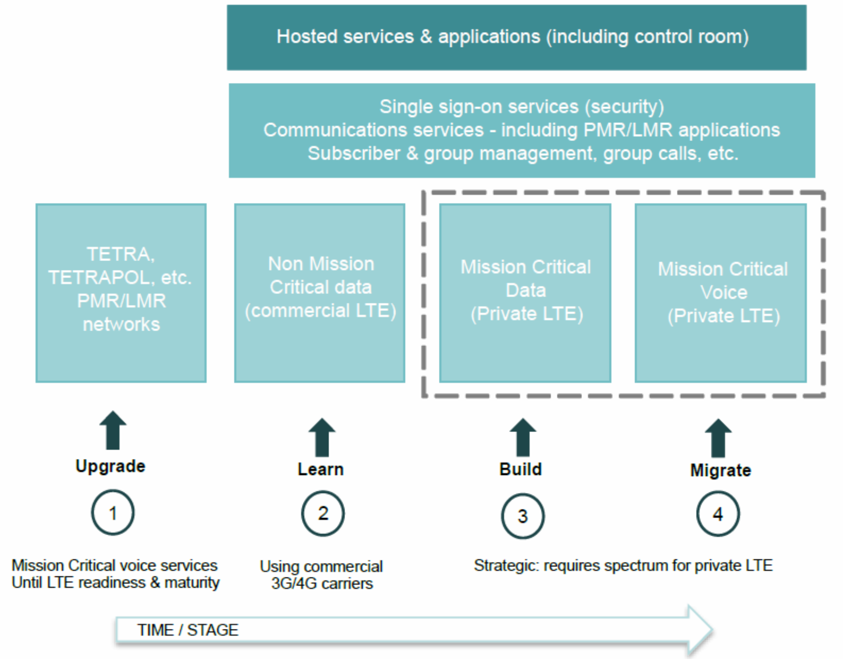


Figure 6.139: Anticipated evolutionary path of mission-critical PPDR services [Source: TCCA CCBG, 2013]

In conclusion, within the 2022 horizon of this study it is anticipated that there will still be narrowband networks in place, and very limited opportunity for technology enhancements to give spectrum benefits, although there will be efficiencies only benefit when narrowband spectrum will be given up.

Technology trend	Short term	Medium term	Long term
Adoption of new technologies	=	=	=

Figure 6.140: Impact of adoption of new technologies

6.11 Radio astronomy (Science)

In the context of this study, the most important service under this heading is the radio astronomy service (RAS). Radio astronomy uses extremely sensitive radio antennas to detect very faint radio signals of cosmic origin.[123] It analyses the radio spectrum across different frequencies in order to gather scientific information about the universe. In the same way as optical telescopes gather light emitted from distant regions of space, radio telescopes typically use of large radio antennas to passively listen for electromagnetic waves outside the visible spectrum.

Figure 6.141: Sardinia Radio Telescope of the Italian National Institute for Astrophysics (64m diameter parabolic radio telescope operating in the 0.3–116 GHz frequency range). [Source: CRAF, 2013]

The intensity of the radiation being studied can show variations, arising from intrinsic variability in the source[124] or from propagation effects.[125] Therefore, radio astronomical observations need to be stable as a function of time. This stability puts requirements on the equipment and also on the levels of interference that can be tolerated within the frequency bands used. Since it is a passive application and the cosmic radio signals are very weak, radio astronomy is very sensitive to interference generated by other systems. An international organisation, the Committee on Radio Astronomy Frequencies (CRAF)[126] has been established to ensure that the frequency bands used for radio astronomy observations remain as free from man-made interference as possible. CRAF, which represents European radio astronomers and observatories, participates in the ITU and the

123 ITU defines radio astronomy as astronomy based on the reception of radio waves of cosmic origin.

124 E.g. regular pulses from pulsars, irregular outbursts from interacting stars and active galactic nuclei.

125 E.g. interstellar and interplanetary scintillations.

126 http://www.craf.eu

CEPT and is actively involved in the protection of the frequency bands designated to and used by the Radio Astronomy Service. In order to support research and minimise interference, radio astronomy frequency designations may be made on a geographical basis.

The frequencies that radio astronomers want to observe at are dictated by the physical processes in the universe, so radio astronomy cannot be shifted or re-designated to other frequencies. Further, in order to gather as much data as possible, it is necessary to operate many observatories with various characteristics and at diverse locations, in order to observe a large number of frequency bands. According to CRAF, 70% of observations are performed outside of the bands designated to radio astronomy. There are several reasons for this:

- not all features of scientific interest fall within radio astronomy designations
- some observations require a large bandwidth (much greater than 100 MHz, i.e. larger than the designated bandwidth) to achieve adequate sensitivity to capture very weak signals
- the movement of astronomical objects may shift radio signals outside the designated bands (due to the Doppler effect).

For such reasons, it is very likely that at least some radio telescopes will be operating within frequencies that are used by other services (or are adjacent to them), and will be vulnerable to interference from the transmitters of active services. This is particularly the case when adjacent bands are designated to active services that operate with high power levels. The difference between the strength of cosmic signals and transmissions from active users can be hundreds of decibels, which poses extremely demanding requirements on the linearity, filtering and other components in radio astronomy systems, which in many cases cannot be fulfilled.

Since radio astronomy is a passive service and no signal is broadcast from the ground, for other spectrum users the radio astronomy bands seem empty. However, the social impact of this kind of application is non-negligible: the whole of humanity can benefit from the scientific discoveries resulting from research, and radio astronomy also acts as an engine for technological development. Therefore, it is commonly accepted that designations to the radio astronomy service should be kept and protected, and that some blocks of spectrum used by radio astronomy need to be adequately protected from harmful interference – in particular, attention should be given to which services are allowed to operate in adjacent bands. It is extremely important that designations to radio astronomy are equal in different countries, at least in all European countries. If possible, designations should be extended in order to allow radio telescopes to use larger bandwidths and thereby achieve higher sensitivities. This results in a growing demand for spectrum *designation* for radio astronomy. In the context of this study, this means a growing *usage* demand, even though strictly speaking radio astronomy does not actively use (transmit within) its spectrum.

Figure 6.142: Summary of spectrum demand drivers for science and educational applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

Science and education	Short term	Medium term	Long term
Usage demand	=	=	=
OVERALL ASSESSMENT	**=**	**=**	**=**

6.12 Satellite systems (Satellite)

Satellite communications systems allow for the deployment of networks with very wide coverage and high capacity. Such characteristics are very much appreciated by a number of different types of users, the main ones being:

- companies needing to exchange live data from anywhere to anywhere in the globe (e.g. TV broadcasters, operators of geographical positioning systems)
- owners of ships and aircraft, for whom satellite may represent the only possible means of communication
- communities living in remote areas, or individuals and companies operating where there are no commercial mobile networks
- organisations involved in disaster relief operations.

The advantages of satellite communications come at a high price compared to other communications systems: the satellites themselves are extremely expensive to build and launch into orbit, and the costs of operating them are also significant.

The nature of the satellite technology is such that it needs coordination at a global level. ITU-R is in charge of coordinating the delicate process of satellite frequency designations and the definition of orbital arrangements, allowing for the effective coexistence of several different operators and their satellite equipment. Satellite systems are designed to work for at least 15 years after setup,[127] and operate according to the specifications chosen during the project phase, in terms of their operating frequency, orbital trajectory and so on. Changes to any of these parameters are very costly after launch, and this allows the prediction of future spectrum demand for several years in advance.

Within the range of frequencies considered in the present study, satellite systems operate in the L-band (~1–2 GHz), S-band (~2–3 GHz), and C-band (~3–7 GHz). As detailed in the following subsections, overall we expect a moderate increase in spectrum usage. For the L-band, we did not find evidence of any expected change in demand. Within the S-band, we envisage an increase in usage due to growing numbers of end users of satellite-based telecoms services and an increase in the average amount of data traffic per user. Demand for the C-band may also increase, due to the general surge in data traffic

Figure 6.143: Summary of spectrum demand drivers for satellite applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

Satellite	Short term	Medium term	Long term
L-band (~1–2 GHz)	=	=	=
S-band (~2–3 GHz)	=	+	+
C-band (~3–7 GHz)	= / +	= / +	= / +
OVERALL ASSESSMENT	**= / +**	**+**	**+**

127 E.g. SES's satellites have a design life of 15 years (for an example, see http://www.ses.com/4629013/nss-12).

6.12.1 L-band (~1–2 GHz)

The following satellite applications are designated to operate in the L-band:

- meteorological satellites and other active sensors used to monitor atmospheric and terrestrial natural activities
- telecoms services[128]
- geo-positioning systems
- amateur applications.

Data on the current and future utilisation of the L-band is scarce, and none of the stakeholders participating in the interview programme provided any information about an increase of demand.

In Section 6.2 we mentioned that the initial success of DAB in some countries such as the UK has led to the suggestion that digital radio services might be moved to the L-band. However, this shift is highly uncertain and depends on a number of separate outcomes, such as the more widespread success of DAB and its move from VHF to the L-band. Thus, we have not considered this possibility here, and we therefore assume that spectrum demand in the L-band stays constant.

Technology trend	Short term	Medium term	Long term
Demand for L-band	=	=	=

Figure 6.144: Impact of demand for L-band

6.12.2 S-band (~2–3 GHz)

The S-band is designated for:[129]

- commercial telecoms services, transporting both voice and data
- space research and passive sensors (scientific uses such as radio astronomy).

Since the second use has already been discussed in Section 6.11, we here consider only telecoms applications.

According to Inmarsat, the number of mobile satellite services (MSS) terminals operating on its network has grown, on average, by 7% per year between 2006 and 2011 (see Figure 6.145). Should this trend continue, in the next ten years the number of terminals is likely to double with respect to the current base. Since the amount of data traffic per terminal will also increase, demand for S-band spectrum is expected to surge.

128 As recommended by ITU (IMT-2000).

129 ECO Frequency Information System (EFIS).

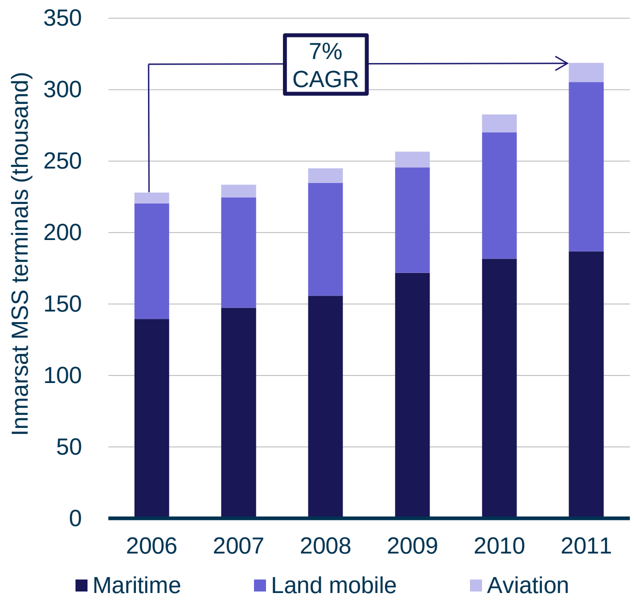


Figure 6.145: Number of MSS terminals in Inmarsat's network, 2006–2011 [Source: Inmarsat]

In 2009, the EC awarded Solaris and Inmarsat a part of the S-band spectrum.[130] We understand that since then, Inmarsat has had its S-band satellite project (EuropaSat) on hold, whilst Solaris has actively engaged with vendors, operators and Member States in order to establish a clear roadmap for the successful launch of these new services. However, we do not have clear evidence of the success of these services to date, three years after the spectrum was awarded. Although success is not assured, we would expect that these efforts will pay off in the near future, and that eventually a Europe-wide communications network will start operations, thus implying additional spectrum usage demand.

European spectrum assignments run until 2027, and satellite operators claim that they are still investigating a number of potential applications for its use. Moreover, the European Space Agency (ESA) is still funding studies into these services using the S-band.

Satellite communications have a number of features – such as global coverage, resilience and security – that might be expected to be attractive to the growing M2M market. At present that market is mainly served by mobile cellular networks, which carry 98% of the traffic generated by M2M applications and capture 94% of the revenues. We do not expect this situation to change, mainly due to the fact that satellite solutions are generally more expensive than mobile ones, and are subject to higher latency. This latter limitation makes satellite-based M2M systems non-viable for many critical applications, such as the monitoring of power grids.

Overall, given the expected increase both in the number of satellite-based mobile terminals and in the average traffic per user, we anticipate that demand for S-band to grow in the medium and long term.

Technology trend	Short term	Medium term	Long term
Demand for S-band	=	+	+

Figure 6.146: Impact of demand for S-band

130 2×15MHz was awarded to each operator (1980–2010MHz and 2170–2200MHz).

6.12.3 C-band (~3–7 GHz)

The C-band is much valued as it is contains quite a large amount of spectrum at relatively low frequencies which have superior propagation characteristics (allowing very wide coverage) and less susceptibility to rainfall and humidity (enabling signal resiliency) than frequencies in the K-band.[131] There are over 160 satellites providing C-band services; at least 25 of these cover Europe.[132] An example of a C-band satellite with almost global coverage is given by the NSS-12 satellite operated by SES. It has 40 transponders operating in the 3625–4200 MHz range and is used to provide intercontinental telecoms links between all continents. It is estimated to reach two thirds of the world's population (see Figure 6.147 below).[133]

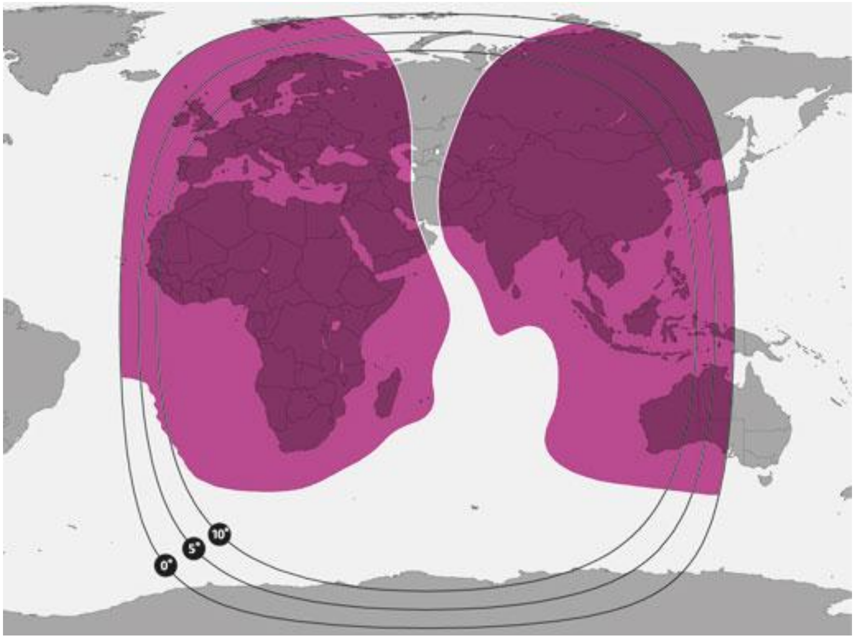


Figure 6.147: Coverage of the C-band satellite NSS-12 [Source: SES, 2013]

C-band satellites are operated with a number of different aims, which include:

- data backhauling and trunking, mainly where no fibre optic links are available (e.g. remote islands or isolated regions)
- distribution of raw broadcast content (e.g. from production to distribution site)
- distribution of TV channels to the headends of cable TV networks
- VSAT (very small aperture terminal) telecoms systems, used to deliver services such as bank transactions, emergency links, maritime communications, distance learning and telemedicine
- uplink communications with mobile, positioning and tracking satellite systems.[134]

131 Radio signals in the K-band (18–26.5GHz) are easily absorbed by water vapour. In contrast, the C-band has low susceptibility to humid environments, and for that reason the C-band is usually chosen for communications and broadcasts aimed at regions such as equatorial Africa, Asia and South America.

132 Radio Spectrum Committee - 10 March 2009, Report On The Impact Of Commission Decision 2008/411/EC On The Fixed Satellite Service And Proposals For Change (RSC#27 Item 6.1 - Presentation from the satellite industry).

133 See previous footnote.

134 For example, Galileo positioning satellites are equipped with C-band antennas to receive tracking, telemetry and control data from the Galileo data dissemination network (GDDN).

In Europe, the C-band is mainly used by professional services, due to the high costs associated with the equipment required to operate in such a band. Some immigrant communities living in Europe may use C-band receivers to receive their native satellite TV channels,[135] but in general the Ku-band (upper K-band) is now used for almost all TV distribution to the home via satellite.

Ground sites primarily comprise sites operating VSAT applications. According to data provided by Intelsat and SES,[136] the number of registered ground sites (i.e. the ones communicating bi-directionally) using the C-band grew by 13% per year between 2006 and 2008, reaching a total of over 1400 at the end of 2008.[137] (We have no further data for the period between 2008 and 2012.

The Galileo data dissemination network (GDDN) is the network side of the Galileo satellite positioning system, to be used for data transmission between the main ground sites; it will be operational by the end of 2013. Links between the ground and Galileo satellites will be deployed in C-band worldwide as in the majority of cases the stringent GDDN continuity performance requirements cannot be met economically by other means.[138]

In summary, we expect that the increase in bandwidth required for backhaul and trunking services, professional services, and the continuously increasing bitrates used for of video distribution will be the main trends pushing spectrum demand upwards. According to estimations based on satellite capacity inputs provided by Intelsat and SES,[139] incremental spectrum usage demand may eventually be served by spectrum in the 3.4–3.8 GHz range, which is currently the least intensively used within the C-band.

Technology trend	Short term	Medium term	Long term
Use of C-band	= / +	= / +	= / +

Figure 6.148: Impact of use of C-band

135 Such TV reception does not directly impact on spectrum demand.

136 In 2011 Intelsat and SES had an overall market share of 46% (Source: Northern Sky Research, Global Assessment Of Satellite Supply And Demand, 9th Edition).

137 Radio Spectrum Committee, RSC#27 Item 6.1 (see footnote 132).

138 Radio Spectrum Committee – 25 June 2009, Draft Guidance to the effective implementation of Commission Decision 2008/411/EC on 3400-3800 MHz (RSCOM09-31).

139 See previous footnote.

6.13 Short-range devices (SRD)

SRDs are radio frequency transmitters used for the exchange of information between pieces of equipment in relatively close proximity. These devices function at low power levels, have a limited range of use, and do not require a licence to be operated. They include a range of wireless equipment, including access control systems, alarms and movement detectors, closed-circuit television (CCTV), industrial control equipment, medical implants, vicinity radars, remote control devices, power meters, radio frequency identification (RFID), road transport telematics, telemetry, and many others. SRDs usually operate in licence-exempt spectrum, which includes:[140]

- 13.56 MHz, 40 MHz, 433 MHz, 2.4 GHz, and 5.8 GHz globally
- 868 MHz and 915 MHz in Europe, USA, Canada, Australia and New Zealand.

A number of very widespread applications such as Bluetooth and Wi-Fi also operate in the 2.4 GHz band, sharing spectrum with SRDs for the 2450–2483.5 MHz range of frequencies.[141]

A summary of our view of the main developments in SRD applications that will impact on spectrum usage demand is provided in Figure 6.149, and discussed in more detail below

Figure 6.149: Summary of spectrum demand drivers for SRD applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

SRDs	Short term	Medium term	Long term
Take-up of automotive SRDs	+	+	+
Growth in the use of SRDs for medical apps	+	+	+
Growth of RFID devices	+	+	+
Growth of alarms	+	+	+
Growth of home and building automation	+	+	+
Harmonisation of modulation techniques	=	-	-
New requirements in the automotive industry	+	+	+
OVERALL ASSESSMENT	**+**	**+**	**+**

Take-up of automotive SRDs

Automotive SRDs include devices for keyless car access and ignition, personal car communication, tyre pressure monitoring, communication between trucks and trailers, and many others. Moreover, there are a growing number of innovative SRD systems on the market, such as devices for vehicle security, diagnostic data exchange, freight protection and environmental monitoring and control.

140 EETimes, Understand wireless short-range devices for global license-free systems - 3 July 2007 http://www.eetimes.com/design/microwave-rf-design/4018891/Understand-wireless-short-range-devices-for-global-license-free-systems?pageNumber=0

141 ECO Frequency Information System (EFIS).

Decision 2011/829/EU allots bands 24.05–24.25 MHz, 63–64 GHz and 76–77 GHz to road transport and traffic telematics, and the EC has mandated CEPT to consider new designations options in the 77–81 GHz range. In-vehicle monitoring systems operate either in 433 MHz or 868 MHz.

Previously, market analysts anticipated that SRDs would become common in vehicles across Europe by 2013, but in fact take-up has been very low so far. This means that the allotted spectrum is sufficient for current spectrum demand. Nevertheless, we believe that the automotive industry is likely to be one of the greatest users of SRDs in the future. Take-up of SRDs will be the result of two different trends:

- increase in the number and variety of SRDs used in vehicles
- increase in the number of cars equipped with SRDs.

Such trends are expected to lead to an increase in the use of spectrum for automotive SRDs.

Technology trend	Short term	Medium term	Long term
Take-up of automotive SRDs	+	+	+

Figure 6.150: Impact of take-up of automotive SRDs

Growth in the use of SRDs for medical applications

SRDs are used for medical purposes during surgery and to monitor patients both in hospital and at home. Current devices include cardiac pacemakers, on-body monitoring devices and therapy monitoring systems (such as glucose measuring devices implanted within the body). As an indication of the prevalence of medical SRDs, three million active medical implants were in use in Europe in 2006.[142]

Currently, medical SRDs largely operate in the range 401–406 MHz, though several other portions of spectrum have been proposed in the 600 MHz, 1400 MHz, 2 300 MHz and 2 400 MHz bands.

The number of medical SRDs in use is expanding rapidly as new applications and new types of devices emerge. For example, it is estimated that 10% of the European population will be treated with on-body monitors in the next 10 years, equating to 50 million end users.[142] Another example is the growing use of SRDs to monitor the glucose levels of people affected by diabetes. Since there is a dramatic upward trend in the incidence of this condition, and since every diabetic needs a glucose measuring device, the CEPT forecasts that there is a market potential of 170 million units per year globally (10–15% of these in Europe).[142]

We therefore expect that in the next few years, SRDs will be used more and more for the treatment and monitoring of health-related issues, and radio spectrum usage will increase as a direct effect.

Technology trend	Short term	Medium term	Long term
Growth in the use of SRDs for medical apps	+	+	+

Figure 6.151: Impact of growth in the use of SRDs for medical applications

142 Report from CEPT to the European Commission in response to the Mandate to: Develop a strategy to improve the effectiveness and flexibility of spectrum availability for Short Range Devices (SRDs) – July 2006.

Growth of RFID devices

Radio frequency identification (RFID) is defined as the use of electromagnetic radiating waves or reactive field coupling in the radio frequency portion of the spectrum to communicate to or from a tag through a variety of modulation and encoding schemes to uniquely read the identity of a radio frequency tag or other data stored on it.[143] There are a large number of different RFID applications, among which are the following:

- logistics and materials handling
- asset monitoring and maintenance
- item flow control in processes
- inventory audit and security control
- payment systems
- authentication
- automatic display of information
- waste management
- libraries
- medical applications
- animal identification.

The main frequency range for RFID devices is 856–868 MHz. ETSI has identified 870–876 MHz for non-specific SRDs and 915–921 MHz for future use by high-power devices such as RFIDs.

The number of RFID devices is expected to grow enormously in the medium and long term due to the proliferation of their range of uses in industry, manufacturing, logistics and many applications in daily life. This growth will be supported by the introduction of economically priced RFID tags and readers. The value of the global market for RFID tags rose from USD6.5 billion in 2011 to USD7.67 billion in 2012, an increase of 18% (see Figure 6.152). By 2019, the number of RFID tags in use worldwide is expected to grow 170 times with respect to 2009 (see Figure 6.153).

	2009	2010	2011	2012
Value of global market for RFID tags (USD billion)	5.56	5.63	6.5	7.67

Figure 6.152: Value of global market for RFID tags, 2009–2012 [Source: IDTechEx]

	2009	2014	2019	2022
Number of RFID tags worldwide (billion)	0.7	5	124	354

Figure 6.153: Forecast of number of RFID tags in use globally, 2009–2022 [Source: IDTechEx, ECO]

143 EC Recommendation of May 2009 on the implementation of privacy and data protection principles in applications supported by RFID.

Such an explosion in the numbers of RFID devices and their range of applications will naturally mean, in certain scenarios of dense deployment, an increase in spectrum usage demand. This demand will be boosted by further factors:

- the need for higher data transmission speeds (requiring greater bandwidth) in order to ensure reliable reading of data and also for writing data to tags
- the need to use higher power radio transmissions in order to penetrate lossy objects or packaging materials in stacks or pallets (alternatively the reading performance of devices can be enhanced by taking multiple readings at higher data transmission speeds, thereby providing redundancy).

Accordingly, spectrum use will substantially increase over the coming years: ETSI has already identified a need for further spectrum both for RFIDs and for non-specific SRDs.

Technology trend	Short term	Medium term	Long term
Growth of RFID devices	+	+	+

Figure 6.154: Impact of growth of RFID devices

Growth of alarms

Many alarm systems are now battery operated and include radio devices, thereby reducing the cost of installation and giving greater flexibility of use. This holds true not only for fire and smoke alarms, but also for intruder (burglar) alarms[144] and social alarms used by the elderly. Such wireless alarms and monitoring systems are deployed in the 868–870MHz band: higher frequencies (above 1GHz) are not suitable due to the limited transmitting power of the devices and the significant attenuation that such high frequencies experience when passing through walls and so on.

Alarm systems do not transmit significant amounts of data. In theory, the data payload of an alarm system is just one bit, but in practice even in the simplest system that one bit payload is generally packaged into a message of 100 bits or so. Moreover, systems do not just transmit messages when they are in the alarm condition: most also send routine supervisory and administrative messages, and are actively monitoring not just for an alarm condition, but also for fault conditions and for tampering and interference

► *Social alarms*

Social alarms are a range of SRDs used by the elderly or by people with limited mobility. Such alarms can be automatically triggered by sensors or manually activated in case of need, and send a signal to a central unit which initiates appropriate actions. The aging population of Europe and the declining prices of these devices have led to a rapid increase in the number of social alarms. In 2005 an estimated 734 000 social alarms were sold in Western Europe and the market was estimated to be worth USD220 million.[145] Between 2005 and 2012 that market expanded by an estimated 6.1%, and now 4.5% of people aged 65 and above use such devices as part of the health

144 These typically use technologies such as a PIR (passive infrared) sensors to detect motion.

145 AEGIS Spectrum Engineering: Short-range devices operating in the 863-870MHz frequency band (Final report for Ofcom, August 2010)

and social care services they receive.[146] Data for the UK records that in 2010 there were 1.8 million installed units, and this number is forecast to undergo a 15% growth in the near future.[147]

► *Fire and smoke alarms*

In Europe, fire and smoke detectors are mandatory in all public and commercial buildings. Typically, *wireless* systems are installed in commercial and industrial premises (e.g. shops, offices and factories), and in other situations where a wired installation would cause disturbance or be costly. *Wired* systems are usually deployed in new buildings, though some wireless components are still used. In the long run, it is expected that all new fire alarms will be completely wireless.

In 2010, in the UK there was an installed base of 10.2 million devices; the vast majority of these are in public and commercial buildings (93% of the market in 2012).[148] Their increased use has had a very marked impact on the number of deaths from fires: since the introduction of the legal requirement for alarms in 1992 the number of fire-related deaths has dropped by up to 40%. Because of this success, smoke detectors will become mandatory in every house or flat in Europe in 2015. The number of devices in use will therefore increase very significantly in the next few years.

► *Intruder alarms*

Wireless intruder systems are deployed mainly in residential settings, while commercial and industrial users prefer wired solutions, which are perceived as having greater reliability. In volume terms, the residential market for wireless intruder alarms is estimated to be 10 times the total commercial market.[149]

Intruder alarms use an array of sensors distributed around the premises: residential systems typically employ 10–15 such devices. These sensors communicate with a central hub unit, and this communication may be unidirectional or bidirectional (to enhance reliability). There is an increasing trend towards sensors using bidirectional communication.

In 2010, 30%–50% of alarm systems in the UK were estimated to be wireless, but by 2020 it is expected that 100% of installations will be wireless systems. There are roughly 700 000 new installations per year in the UK, with an average of 8–10 devices per installation; this represents an increase of 7 million devices each year.[150]

In summary, the increasing number of alarms of these various types will lead to a growth in spectrum usage in the future.

Technology trend	Short term	Medium term	Long term
Growth of alarms	+	+	+

Figure 6.155: Impact of growth of alarms

146 AEGIS Spectrum Engineering, 2010 – see footnote 145.
147 AEGIS Spectrum Engineering, 2010 – see footnote 145.
148 AEGIS Spectrum Engineering, 2010 – see footnote 145.
149 AEGIS Spectrum Engineering, 2010 – see footnote 145.
150 AEGIS Spectrum Engineering, 2010 – see footnote 145.

Growth of home and building automation

Home automation applications include shutters, curtains, electrical door locks, electrical windows, garage door and gate openers and devices for controlling heating and lighting. In Europe, these devices typically operate in the 433MHz and 863–870MHz bands; they communicate at 19.6 to 38.4kbit/s and typically have a range of 400 metres.

Figure 6.156 shows the CEPT's 2006 estimates for sales of home and building automation devices in Europe in 2005 and 2010.[151] Yet during 2007 more than 17 million devices were sold, 25% more than CEPT's prediction. This growth was achieved as a consequence of considerable investment by manufacturers, and market data shows that this trend will continue.

Home and building automation: number of devices	2005	2010	CAGR
Annual (million)	5	10	15%
Cumulative (million)	10	70	48%

Figure 6.156: Home building and automation devices in Europe [Source: CEPT Report 14]

The increasing popularity of these devices, and the continuous evolution in their sophistication and functionality, will lead to greater use of spectrum. So far, most of these appliances have been used as stand-alone devices that perform a single function, and simple command protocols were sufficient. Now the need for more comfort, more security and a strong emphasis on energy saving require the use of more complex systems that use advanced protocols, and thus use more spectrum.

Technology trend	Short term	Medium term	Long term
Growth of home and building automation	+	+	+

Figure 6.157: Impact of growth of home and building automation

Harmonisation of modulation techniques used by SRDs

Most types of SRDs do not need a licence to be operated, are affordably priced and easily portable. This means that consumers can easily take them abroad when they travel. Moreover, commercial goods carrying RFID tags are regularly transported between countries. It is thus reasonable to conclude that vendors, service providers and end users all require that such devices be fully functional and interoperable in all places. One step necessary to achieve this is harmonisation of the modulation techniques used by SRDs, to allow for operability across countries. For example, if a standardised set of modulation techniques were used for RFID tags in all regions, vendors could focus on improving the technology, shippers and traders could streamline the range of devices they needed to use, and final users would receive a more efficient and cost-effective service.

151 CEPT report 14, 2006.

In order to support the free and unconstrained flow of people and goods within Europe, harmonisation of modulation techniques is an essential step to undertake. Harmonisation would also bring benefits for other industrial, scientific and medical SRD applications – for example, assisting the emergence of new technologies. Another benefit is that the harmonisation of modulation techniques can improve spectrum efficiency, reducing spectrum usage demand and coping with the increase in the number of SRD applications.

Technology trend	Short term	Medium term	Long term
Harmonisation of modulation techniques	=	-	-

Figure 6.158: Impact of harmonisation of modulation techniques

New requirements in the automotive industry

There are a number of SRD applications for vehicles that can improve safety on the roads, providing improved interfaces and additional services to drivers. Safety and security applications within the automotive sector are given the utmost importance by the EC and by regulators in general. For example, the EC considers tyre pressure monitoring systems (TPMS) to be an integral part of the additional measures defined in order to reduce the average CO_2 emissions of cars to 120g/km. By November 2014, TPMS will be mandatory for all new passenger cars sold in the EU.

In the USA, the Federal Communications Commission (FCC) recently designated 75 MHz of spectrum in the 5.9 GHz band for use by intelligent transportations systems (ITS), a range of vehicle safety and mobility applications (see Section 6.6). The US Department of Transportation will likely require that such equipment be installed in all new cars from 2015.

As a result of these developments, both in Europe and the USA car makers will soon include specific SRDs as standard equipment in their vehicles. Accordingly, as the number of SRDs in vehicles increases, demand for spectrum is set to significantly expand in the coming years.

Technology trend	Short term	Medium term	Long term
New requirements in the automotive industry	+	+	+

Figure 6.159: Impact of new requirements in the automotive industry

6.14 WLAN/RLAN (WLAN)

In the next few years, it is expected that consumer devices such as smartphones, tablets, PCs and connected TVs will generate a large increase in data traffic, driven by a general increase in the sophistication of devices and the widespread consumption of enhanced media content. A significant proportion of such consumer devices include a Wi-Fi module. In addition, many mobile phone users prefer to access the Internet via Wi-Fi networks when these are available, both to take advantage of the better performance of such networks and to cope with the monthly data usage caps imposed by mobile operators.

Over the next decade, the extensive deployment of both private and public Wi-Fi hotspots, and the roll-out of rural wireless access networks to remote locations, will create a constantly and significantly increasing demand for spectrum (see Figure 6.160). In the following subsections we consider these wireless applications in more detail.

Figure 6.160: Summary of spectrum demand drivers for WLAN applications and assessment of their impact on spectrum usage demand [Source: Analysys Mason, 2013]

WLAN/RLAN (formerly wideband data transmission systems)	Short term	Medium term	Long term
Continued growth in Wi-Fi network reach and increased user adoption	++	++	++
Growth in the number of hotspots	+	+	+
Growth in rural fixed wireless access	=	-	-
Release of spectrum designated for WiMAX use	=	=	= / -
OVERALL ASSESSMENT	**+**	**+**	**+**

Continued growth in Wi-Fi networks

According to ABI Research,[152] the number of Wi-Fi-enabled devices will grow at 31% per annum during the period 2012–2017 (see Figure 6.161 below). These will increase the amount of traffic carried over Wi-Fi networks. In particular, smartphones and tablets are the devices which generate most Wi-Fi traffic. According to the results of a real-world tracking experiment conducted in 2012 by Analysys Mason[153] on 1000 mobile users in a number of European countries, 59% of smartphone traffic transits through Wi-Fi networks, and the rest through mobile networks (see Figure 6.162 below).

152 http://www.abiresearch.com/research/product/1015841-wi-fi/

153 Consumer Smartphone Usage: Key Findings From An On-Device Tracker, 25 May 2012

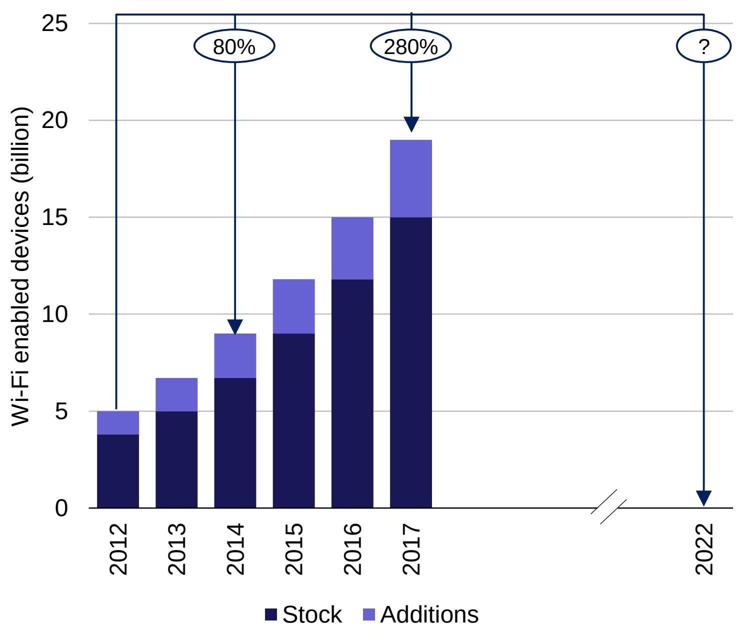


Figure 6.161: Sales forecasts for Wi-Fi-enabled devices, 2012–2017 [Source: ABI Research]

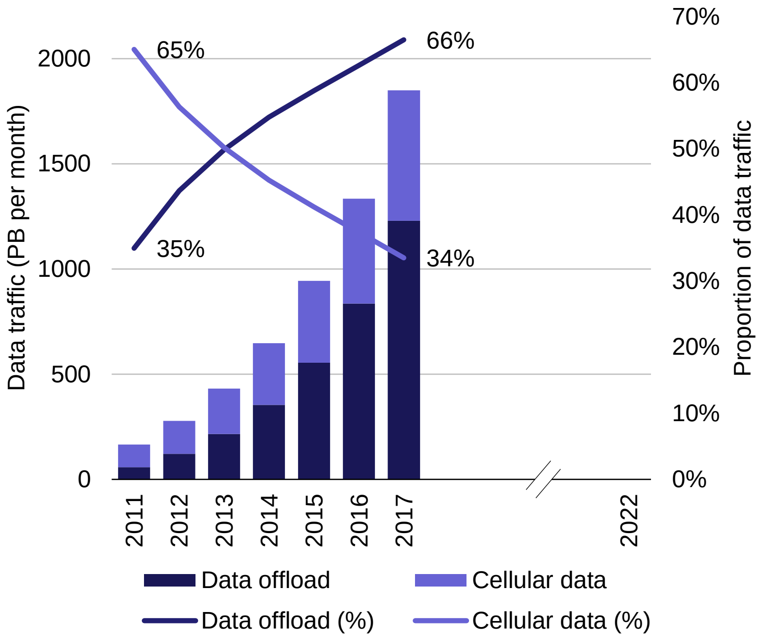


Figure 6.162: Forecast of traffic volume and proportion generated by mobile devices in Europe by type of network, 2011–2017 [Source: Analysys Mason, 2012]

As consumers take up more sophisticated mobile devices and enjoy the applications and services these devices provide, traffic will increase greatly. Analysys Mason expects traffic from smartphones to grow by 53% *per year* during the period 2012–2017, and traffic from tablets by 155% per year (see Figure 6.163 below).

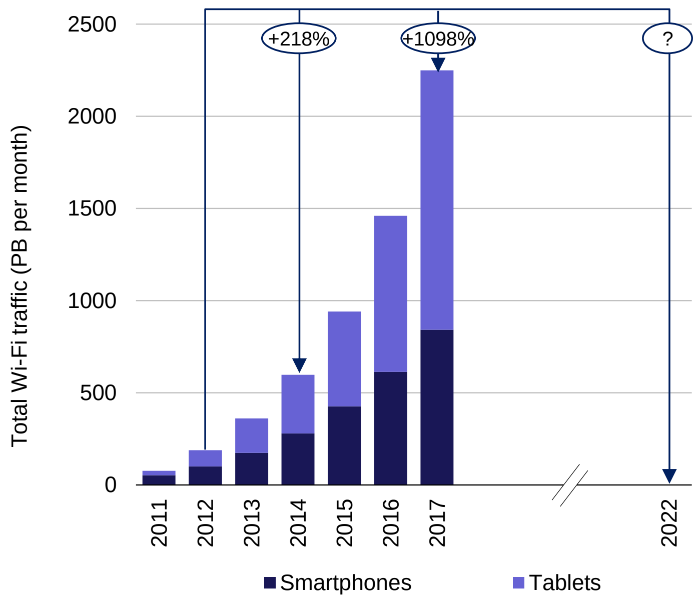


Figure 6.163: Forecast of Wi-Fi usage by device type, 2011–2017 [Source: Analysys Mason, 2012]

As a result of these market developments, we estimate that traffic offloaded to Wi-Fi by consumers will grow by 59% per annum during the period 2012–2017 (while mobile traffic will increase by 32% over the same period). We expect that by 2014, traffic offloaded to Wi-Fi will overtake pure mobile traffic.

Technology trend	Short term	Medium term	Long term
Growth in Wi-Fi traffic	++	++	++

Figure 6.164: Impact of growth in Wi-Fi traffic

Growth in the number of hotspots

The Wireless Broadband Alliance expects the number of *private* hotspots to grow at a CAGR of 16% over 2012–2015, and the total number of *public* hotspots worldwide to grow at a CAGR of 40% (see figures below).[154] Network operators have started to deploy Wi-Fi networks in large cities: for example, in 2012 O_2 rolled out Wi-Fi hotspots in London to support mobile data offload, and in the same year Virgin rolled out a Wi-Fi network covering the London Underground stations, where mobile coverage is absent, allowing mobile users to stay connected while at train stops.

154 http://www.wballiance.com/wba/wp-content/uploads/downloads/2012/07/16_WBA-Industry-Report-2011-_Global-Developments-in-Public-Wi-Fi-1.00.pdf

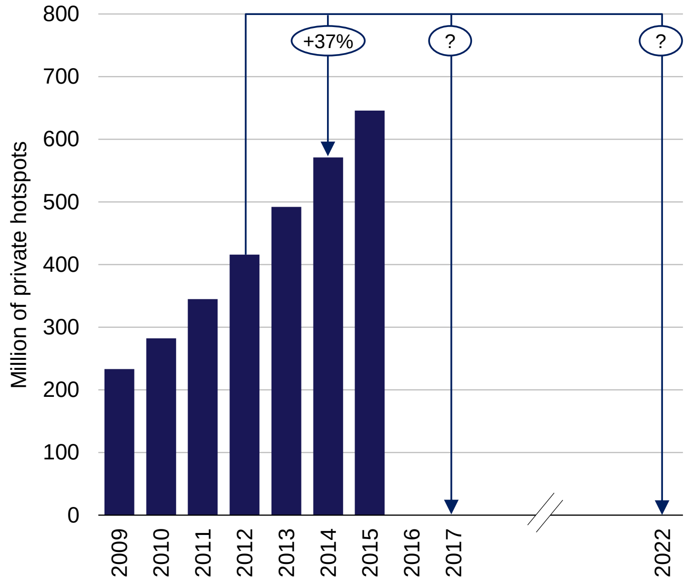


Figure 6.165: Number of private hotspots worldwide, 2009–2015 [Source: Wireless Broadband Alliance]

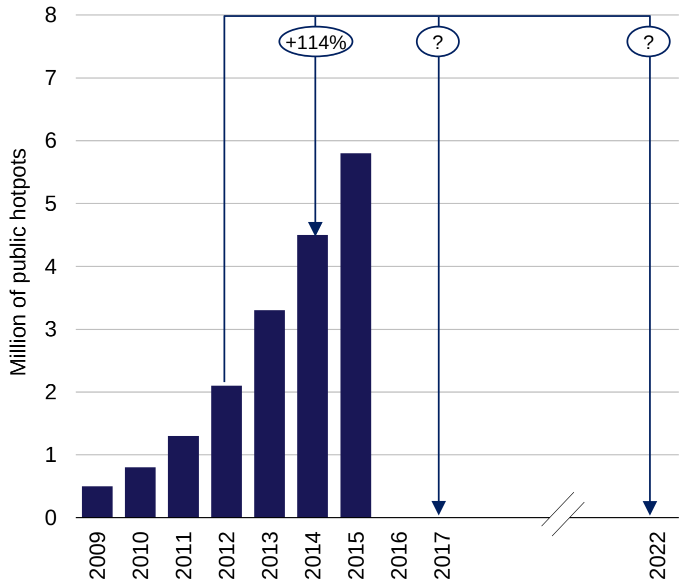


Figure 6.166: Number of public hotspots worldwide, 2009–2015 [Source: Wireless Broadband Alliance]

Public Wi-Fi networks are characterised by limited indoor coverage (circa 30 metres from the access point). This means that frequencies are reusable, and the presence of many hotspots may not imply an increase in spectrum demand. Nevertheless, we understand that the more hotspots are rolled out, the higher the chance of interference between neighbouring networks. Thus, the increase in the number of Wi-Fi hotspots is certainly leading to increase spectrum usage demand, and a deeper investigation should be undertaken in order to understand the need to designate additional bands.

Technology trend	Short term	Medium term	Long term
Growth in number of hotspots	+	+	+

Figure 6.167: Impact of growth in the number of hotspots

Rural fixed wireless access

FWA networks can provide broadband connections to remote locations. The technology of choice for single households is WiMAX, which allows high bandwidth and good resilience. Larger communities can be covered by means of fixed links (see Section 4.5). WiMAX reached its peak in Europe in 2011, with over 1 million subscribers (i.e. 0.7% of total fixed broadband subscribers), before starting to decline.

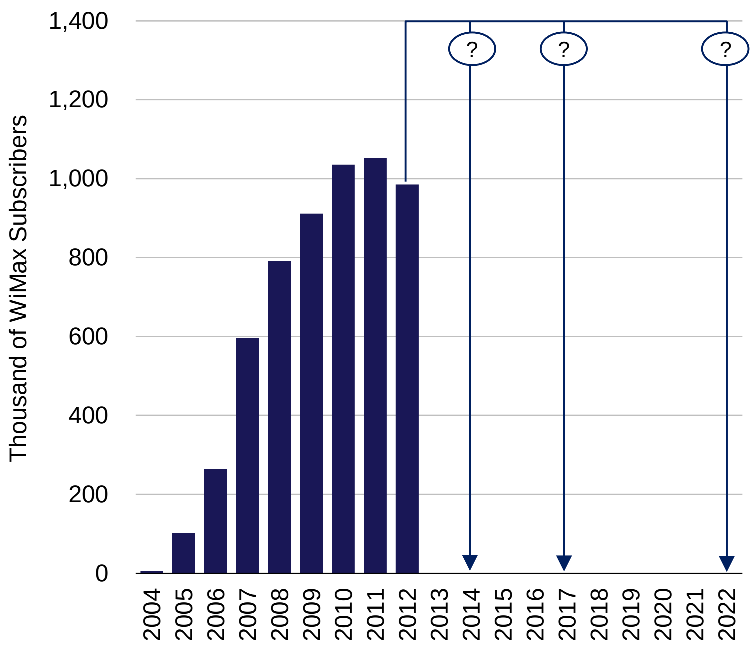


Figure 6.168: WiMAX subscribers in Europe, 2004–2012 [Source: TeleGeography]

Policy decisions may lead to an increase in the use of WiMAX, e.g. to provide rural broadband coverage. However, we believe that the spectrum needs of these networks can be catered for by existing spectrum designated to WiMAX services.

Looking further ahead, the most likely migration path for WiMAX is LTE, in particular TD-LTE. Some operators have already converted their WiMAX networks to LTE. As an example, Yota in Russia recently renewed its WiMAX network, transforming it into an LTE one. We expect this trend to accelerate in the near future. Since LTE networks are more spectrally efficient, in the medium and long term the roll-out of rural FWA networks will result in a moderate decline in spectrum usage demand.

Technology trend	Short term	Medium term	Long term
Rural fixed wireless access	=	-	-

Figure 6.169: Impact of rural fixed wireless access

Release of spectrum designated for WiMAX use

If the number of WiMAX subscribers continues to decline as it started to do in 2012, WiMAX operators may reduce their spectrum holdings upon licence renewal. The spectrum freed up could potentially be designated to Wi-Fi services.

Technology trend	Short term	Medium term	Long term
Release of spectrum designated to WiMAX	=	=	= / -

Figure 6.170: Impact of release of spectrum designated to WiMAX

7 Recommendations

This section presents the results of our analysis of future needs and demand for spectrum across the EU. For each application category, we present:

- *Overview*: A brief summary of the applications within the category.
- *Current spectrum usage*: A look at the current usage of designated spectrum as described in the WIK Study, and a comparative analysis of the average usage in the eight focus countries and the minimum, average and maximum usage across the EU-27 as a whole.[155]
- *Key factors driving spectrum usage*: A brief summary of the main factors (technological or consumer and community related) driving spectrum usage, and their impact on future spectrum demand.
- *Future demand for spectrum usage*: A description and illustration of the future demand for spectrum usage by each category. We describe this for the three time periods separately and also compare scenarios for minimum and maximum potential growth.
- *Differences across countries*: A description and illustration of the differences in future demand for spectrum usage across the eight countries. This discussion is based on average current usage and an average growth scenario.
- *Conclusions*: We present our main conclusions based on the future demand for spectrum usage for the three time periods, touching on any mitigating factors as well as brief recommendations related to the category.

7.1 Aeronautical, maritime and civil radiolocation and navigation systems (AMCRN)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

[155] In some categories there are a higher number of frequencies included in the overview section that appear in the heatmap. It may be because the WIK input data does not show any usage or data for that band or the usage is below 10MHz, which is the minimum that we have considered.

Overview

AMCRN uses globally harmonised spectrum designations for communications, navigations and surveillance in order to provide a safe and efficient global transport system. Currently, AMCRN systems use bands mainly above 1GHz, namely 960–1215 MHz, 1300–1350 MHz, 2300–2400 MHz, 2700–3400 MHz, 4200–4400 MHz, 5030–5150 MHz and 5350–5725 MHz. Some of these frequencies are shared with other application categories such as Meteorology or Defence.

Current spectrum usage

Current spectrum usage by AMCRN systems, as shown in Figure 7.1, seems to be very homogenous across the eight focus countries and across most of the EU-27, in particular in the frequency rages 960–1215 MHz, 2700–3100 MHz, 4200–4400 MHz and in the 5030–5150 MHz band. Usage of the 5030–5150 MHz band, which is limited to aeronautical systems, is low (0–35% of the designated band), while usage of the other frequency bands designated to AMCRN is high (75–100% of the designated band).

Figure 7.1: Current average usage by AMCRN for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

Key factors driving spectrum usage

As discussed in Sections 5 and 6, future demand for spectrum for AMCRN services is expected to be driven primarily by the following three factors:

- **Technological advances in radiolocation services** – These services use a large portion of spectrum designations within the L- and S-bands, typically within the frequency ranges 960–1350 MHz and 2700–3400 MHz. The introduction of these new technologies into European airspace is expected to provide benefits not only in terms of safety, cost reduction and efficiency, but also in terms of reduced spectrum usage.

- **The level of demand for, and commercial success of, high-speed broadband and in-flight live TV services**[156] – Demand for high-speed broadband and live TV services in-flight is expected to grow rapidly over the next few years, and this will drive demand for future spectrum usage. The CEPT has already determined that A2G services will require spectrum, with overall demand likely to be either 2×10 MHz FDD or 20 MHz TDD.

- **Integration of RPAS into the civilian airspace** – The number of companies operating RPAS is also forecast to grow rapidly over the next few years. For example, the ITU projects that the number of civil RPAS units will grow by 1250% between 2012 and 2022. This is expected to have a major impact on future spectrum usage demand.

Future demand for spectrum usage

Future demand for spectrum for AMCRN will require careful attention and planning as spectrum usage levels in some bands are likely to exceed the current designations under all growth scenarios in the medium to long term:

- **Short term (2014)** – Future spectrum usage is not likely to exceed the current spectrum designations. Even in the maximum growth scenario, usage of many of the frequency bands used for AMCRN is expected to be low to medium. However, in some bands (960–1215 MHz, 4200–4400 MHz and 5350–5450 MHz) usage levels are high (75–100% of the designated band). The bands where usage is limited might help to accommodate this traffic.

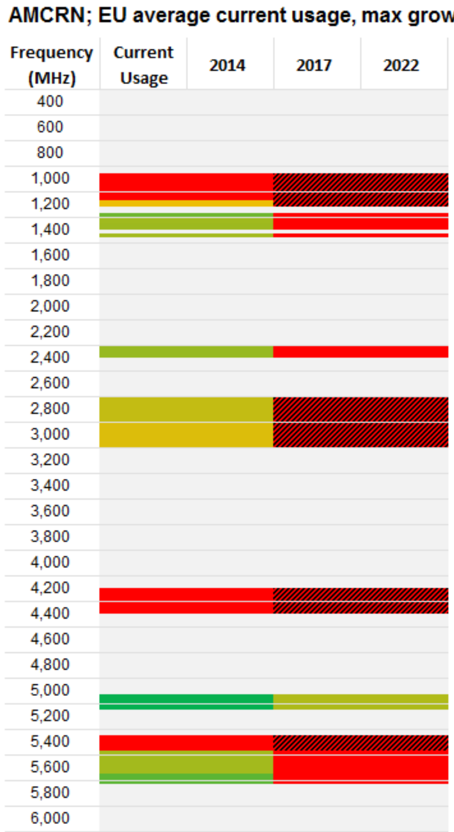
- **Medium term (2017)** – Spectrum usage is likely to exceed designated bands in some existing frequency bands (960–1215 MHz, 4200–4400 MHz and 5350–5450 MHz), even in the minimum growth scenario. However some frequencies (1300–1350 MHz and 5030–5150 MHz) are not expected to be fully utilised and they might help in managing overall demand, if feasible.

- **Long term (2022)** – The aeronautical industry is working to transform its operating practices and re-engineer its infrastructure to accommodate the additional spectrum demands within existing designations. These changes, which will have their full effect only in the long term, include rationalising systems, making systems more spectrally efficient, relying to a greater extent on satellite communications at L-band and C-band, and greater reliance on information from the GNSS. However in some bands, spectrum usage is likely to exceed 100% of designated bands within the next 10 years.

156 These are strictly speaking commercial telecoms services offered to passengers and are not related to safety, and so will not use the aeronautical safety spectrum

Figure 7.2: AMCRN: average current spectrum usage in the EU-27, minimum growth scenario [Source: Analysys Mason, 2013]

Figure 7.3: AMCRN: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]



Differences across countries

Future demand for spectrum usage in the eight focus countries seems to be quite similar:

- Some bands (960–1215 MHz and 4200–4400 MHz) are likely to present a congestion problem (demand is over 100% of the designated band) in all scenarios. The 5350–5450 MHz band will not be fully utilised and might help with additional usage from this category or other categories as they might ultimately serve the same demand (e.g. high-speed broadband and live TV services).
- In Germany and UK, the 2300–2400 MHz band is designated for aeronautical services (in Germany it is shared with Defence, while in the UK it is shared with Defence and PPDR). This band is likely to be harmonised for wireless broadband, and the aeronautical usage will be phased out or must share.
- In France, the 5350–5650GHz band has been designated for aeronautical services.

Figure 7.4: AMCRN: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

Based on average current usage and the different growth scenarios, there seems to be a clear indication that average future spectrum usage for AMCRN applications will exceed 100% of current designated bands in all countries, with the exception of some bands as noted above.

The additional spectrum requirements for new and emerging applications such as unmanned aerial vehicles (UAVs) are placing increased demand on spectrum, and whilst some of this demand can be met through the improved spectral efficiency of new radio systems, it is inevitable that existing spectrum designations will need to be broadened for this type of application. Allocation for UAV use was made at WRC-12 in 5030–5091 MHz.

To reduce the future congestion in the 960–1215 MHz band, some actions are currently under study:

- Implementation of the future air/ground data link, the L-band Digital Aeronautical Communication System (LDACS). The compatibility of LDACS with the radio navigation systems operating in the range 960–1164 MHz (DME, TACAN, SSR)[157] has not yet been established and may be critical.
- Implementation of new DME stations to support RNAV.

157 DME: Distance Measuring Equipment. TACAN: Tactical Air Navigation. SSR: Secondary Surveillance Radar

Spectrum for ground-based radar is potentially easier to free up, as these systems are both stationary and passive (i.e. the radar stations simply measure the reflections that occur when the signal they transmit bounces off, say, an aeroplane, and do not need to actively communicate with a radio device installed on the aeroplane). However, some frequency bands are more suitable for ground-based radar than others. Moreover, ground-based radar can be very long-range, and so international co-ordination may be required before this application can be re-allocated to another frequency band. One of the principal bands currently used for ground-based radar is the 2.7–2.9 GHz band. Work is being carried out in the UK to modify equipment operating at the lower end of this band to avoid interference from 4G mobile systems operating in the 2.6 GHz band when these are launched. We understand that, in principle, the replacement of existing ground-based radar systems with new technologies may enable more of this band to be vacated.

The initial range of bands considered by CEPT ECC FM48 in its on-going report on A2G has now been narrowed down to two main bands: (a) 1900–1920 MHz and 2010–1025 MHz (the so-called unpaired terrestrial 2 GHz band); and (b) 5855–5875 MHz. It is important that the bands chosen for A2G meet the necessary criteria of harmonisation, existing licences and uses, as well as providing sufficient bandwidth to support the anticipated demand.

7.2 Terrestrial broadcasting (Broadcasting)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

Currently, broadcasting services use the frequency band 470–790 MHz.

Current spectrum usage

Spectrum usage by broadcasting services seems to be very homogenous across the eight focus countries, and exhibits medium growth (75–100% of the designated band) (see Figure 7.5). In the UK, 50 MHz of spectrum has been designated in the 1452 MHz band, but usage of this band is low (0–5% of the designated band).

Figure 7.5: Current average usage by Broadcasting for eight countries and EU-27 min, max and average [Source: Analysys Mason, WIK Study]

For consistency with the other categories, our assessment of current spectrum use by broadcasting is based on the WIK Study. However, comparing the eight focus countries, we believe there are some inaccuracies in the study. For example, usage in Italy is shown to be the same as in Germany, the UK and France, yet in Italy there are 16 MUXes compared to only six in the other countries – implying that usage in Italy should be higher than in those countries.

Key factors driving spectrum usage

As mentioned in Sections 5 and 6, future demand for spectrum for broadcasting services is expected to be driven primarily by the following two factors:

- **The implementation and adoption of HDTV, UHDTV and 3DTV** – Penetration of HDTV sets is forecast to double in the next five years (2012–2017) and the number of HD channels is expected to keep growing in several European countries. Penetration of 3DTV sets has started to increase only recently as these sets have become available, and even though we are seeing a proliferation of HD content, the number of movies that can be viewed in 3D is still limited. The increasing take-up of high-quality transmissions, supported both on the end-user side by the introduction of advanced TV sets, and on the production side, will lead to an increased demand for HD and UHD content. This is turn will lead to a significant increase in spectrum usage if it is not supported by more efficient compression standards.
- **Technology migration path** – The migration path for broadcasting technologies will vary by country, but overall this factor is expected to have a major impact on spectrum usage demand, as increased quality and higher compression and encoding standards are adopted. To date, it is mainly the DVB-T standard that has been used in Europe, which enables bitrates of between 8Mbit/s and 27Mbit/s per MUX, depending on the modulation scheme used. DVB-T2 offers higher spectrum efficiency than DVB-T, leading to a wider bandwidth per MUX.

Future demand for spectrum usage

Demand for spectrum for broadcasting services will require careful attention and planning as spectrum usage levels in some bands are likely to exceed the current designations under all growth scenarios in the medium to long term:

- **Short term (2014)** – Even in the maximum growth scenario, spectrum usage is not likely to exceed spectrum supply, in any of the existing frequency bands. However, in the maximum growth scenario, the band shows a high usage (i.e. 75–100% of the designated band).
- **Medium term (2017)** – Spectrum usage is likely to exceed supply, or reach 75%–100% of the designated band.
- **Long term (2022)** – Although higher-spectral efficiency will offset demand to a degree, spectrum requirements are expected to exceed current designations in both the minimum and maximum growth scenarios.

Figure 7.6: Broadcasting: average current spectrum usage in the EU-27: minimum growth scenario [Source: Analysys Mason, 2013]

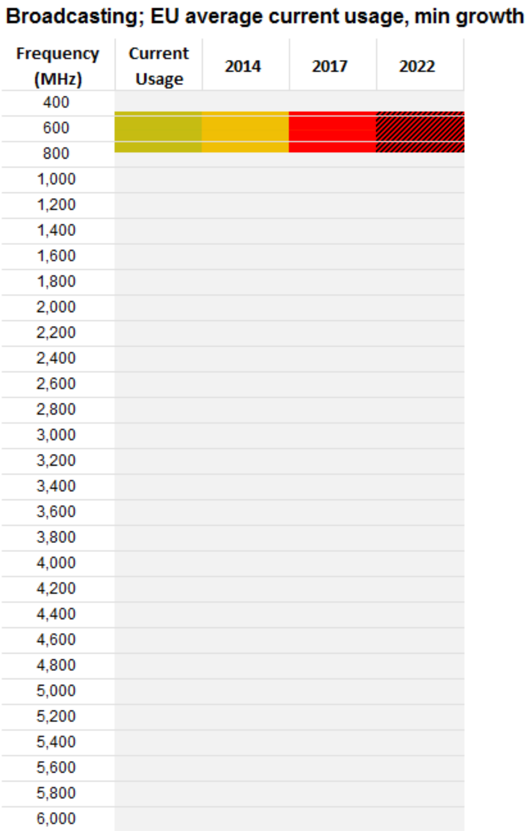
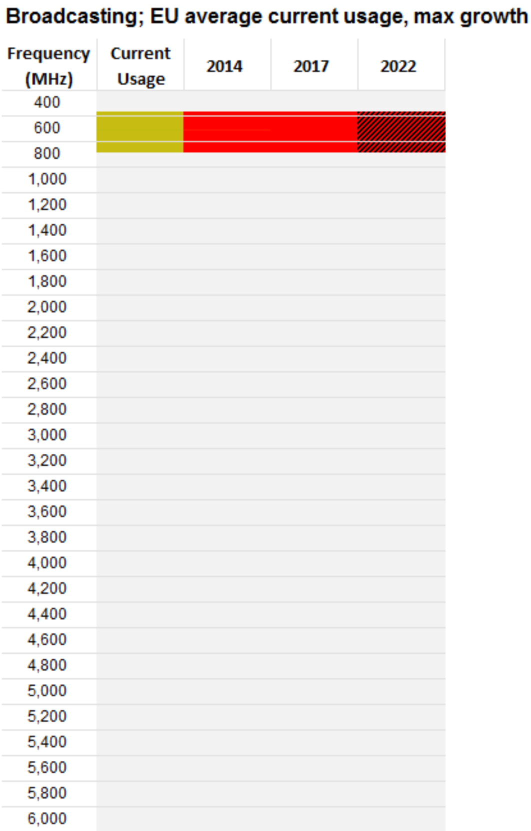


Figure 7.7: Broadcasting: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]



Differences across countries

Future demand for spectrum usage in the eight focus countries seems to be quite similar. In all countries, usage is likely to exceed supply, mainly due to the need to simulcast technologies and formats to help consumers in their transition to HDTV in the short and medium term, and UHDTV in the long term.

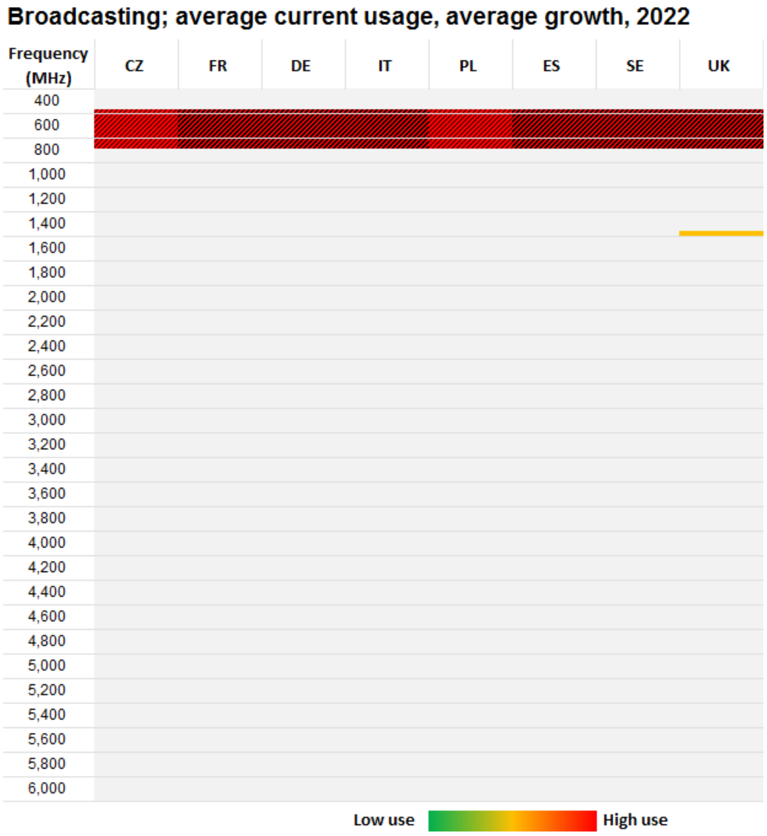


Figure 7.8: Broadcasting: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

The results presented above clearly indicate that in all countries the average future spectrum usage will exceed the current designated bands in the long term (2017–2022) mainly due to the need to simulcast of technologies and formats to help consumers in their transition to HDTV in the short and medium term and UHDTV in the long term.

To satisfy these requirements, a mix of solutions could be considered, such as more intensive use of existing spectrum, the adoption of new, more spectral efficient technologies, and the upgrading of DTT MUXes to DVB-T2 (HDTV) and, in the long term, HEVC (UHDTV). However, we note this trend might not be consistent in all countries, and there may be exceptions like Germany where there appear to be serious doubts about the long-term commitment to DTT that have made RTL take different decisions regarding DTT in Germany and Austria.

In addition, the eventual release of the 700 MHz band from DTT to mobile services, as agreed in some countries, will further reduce the number of channels available for broadcasting, eventually increasing the congestion problem. Some other frequency ranges may be attractive for filling this gap: some EU governments, such as in the UK, are planning to award the 600 MHz spectrum band for broadcasting alongside PMSE, and the Finnish government has licensed three DTT MUXes to operate in VHF frequency bands. Other countries, however, might not offer any spectrum to compensate for the reduction of 700 MHz spectrum allocated to broadcasting, as seems to have been indicated by the government in France.

Some stakeholders suggested that future demand for spectrum usage by broadcasting may be mitigated by the increase in the proportion of TV and radio programmes broadcast via satellite, cable, mobile or Internet. However, other stakeholders argue this would be difficult in countries where DTT is the main TV platform and is likely to remain so for the foreseeable future. We understand that SFN national networks are already in use, and it is unclear that much more efficiency could be delivered without affecting current broadcasters' structures (e.g. regional and local broadcasting services). MFN, though, provides the opportunity to use white spaces in TV spectrum for other services.

Administrative Incentive Pricing (AIP) is expected to be implemented in the UK in 2014 as a tool to promote efficient use of spectrum by broadcasters. The implementation of AIP might lead to less reliance on terrestrial broadcasting and/or promote the adoption of higher compression and transmission standards.

The development of PMSE services is also expected to have an impact on spectrum usage demand by broadcasters.

7.3 Cellular/BWA (Mobile)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

Currently, public mobile services principally use spectrum below 1 GHz (790–862 MHz and 880–915 MHz), as well as spectrum above 1 GHz (1710–1785 MHz, 1805–1880 MHz, 1900–1980 MHz, 2010–2025 MHz, 2110–2170 MHz, 2500–2680 MHz and 3400–3600 MHz).

Current spectrum usage

Current usage of the 880–915 MHz, 1805–1880 MHz, 1900–1980 MHz, 2010–2025 MHz, and 2110–2170 MHz bands for mobile services seems to be highly homogenous across the eight focus countries, and indeed across most EU-27 countries (see Figure 7.9). Usage of most of these bands is high in all the focus countries (75–100% of the designated band).

There is a different situation regarding the 800 MHz band (790–862 MHz), which in six out of the eight focus countries has already been released for mobile services as a result of the digital switchover. Usage in the UK and Sweden is high (75–100% of the designated band), while in the other focus countries usage is in the low-to-medium range (0–50% of the designated band).

The 2.6 GHz band has recently been released for mobile services, and so usage of this band is generally 35–50% of the designated band, with the exception of Sweden and Germany where usage is high (75–100% of the designated band)).

The 3400–3600 MHz band is used for mobile services in some of the focus countries; usage is generally between 35% and 50% of the designated band, except in Czech Republic where usage is high (75–100% of the designated band).

Figure 7.9: Current average usage by Mobile for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

For consistency, as a starting point for current spectrum usage by mobile, we have decided to use the same source of information (the WIK Study) as in other application categories. However, comparing the eight countries, we believe that the study presents some inaccuracies:

- The WIK Study does not show any usage of the 2.6 GHz band in Italy. However, this band was already designated to the four MNOs back in 2011, and should therefore present a low usage profile.
- In the UK, the study describes a high usage of the 800 MHz band, and low usage of the 2.6 GHz band. However, this spectrum has just been auctioned, so there are no mobile services using this spectrum and current usage should therefore be zero.
- The study presents a high usage of 800 MHz and 2.6 GHz in Sweden and Germany. We believe this scenario is too aggressive due to the level of adoption of LTE services in these countries. For example, it was reported that by the end of May 2012 TeliaSonera had gained 140 000 LTE subscribers (using dongles, tablets or smartphones), accounting for about 2% of its total active subscriber base of 6.4 million. This is despite the fact that TeliaSonera introduced LTE in Sweden as early as December 2009. In our opinion the current usage is low rather than high.

Key factors driving spectrum usage

As discussed in Sections 5 and 6, future demand for spectrum for mobile services will be driven primarily by the following three factors:

- **Strong take-up of more sophisticated devices such as smartphones and tablets** – The last five years have seen the mass-market success of devices such as smartphones and tablets. As a result, manufacturers will continue to design and manufacture more sophisticated devices that encourage higher data consumption. As an example, the total number of Internet-enabled devices in Europe is expected to grow by 40% in the short term, and nearly 80% in the medium term.
- **The extent of traffic being offloaded onto Wi-Fi networks (by both consumers and operators)** – Mobile-to-Wi-Fi offload is a growing trend as there are increases in the number of Wi-Fi-enabled devices, hotspots and fixed broadband penetration; Cisco VNI forecasts that in 2017 mobile offload will account for 46% of the total traffic generated through mobile devices, up from 33% in 2012. This may significantly reduce the demand for mobile capacity by using alternative spectrum (above 1GHz).
- **Launch of LTE/LTE-Advanced** – The launch of LTE and LTE-Advanced will offer higher speeds and greater quality of service, as well as a wider range of services to mobile customers, thus encouraging more data consumption.

Future demand for spectrum usage

Future demand for spectrum for mobile services will require careful attention and planning, as in the medium to long term spectrum usage levels in some bands are likely to exceed the current designations under all growth scenarios:

- **Short term (2014)** – Spectrum usage is likely to exceed supply in only some existing frequencies bands under the maximum growth scenario. However, some other frequencies (790–862 MHz, 2500-2690 MHz and 3400-3600 MHz) seem to not be fully utilised, and they might help in managing overall demand. In the minimum growth scenario, the main constraints will be in the 1900–1980 MHz and the 2110–2170 MHz bands.

- **Medium term (2017)** – Usage is likely to exceed supply in many existing frequencies bands, even in the minimum growth scenario. Other frequencies (e.g. 2500–2690 MHz) seem to not be fully utilised (though only in the case of the minimum growth scenario) and they might help in managing overall demand to some extent.

- **Long term (2022)** – Although gains in spectrum efficiencies will offset demand to a degree, spectrum requirements are generally expected to exceed current designations under both growth scenarios. The exception is the 2500–2690 MHz band, which in the minimum growth scenario seems to be underused, and could help managing excess demand.

Figure 7.10: Mobile: average current spectrum usage in the EU-27: minimum growth scenario [Source: Analysys Mason, 2013]

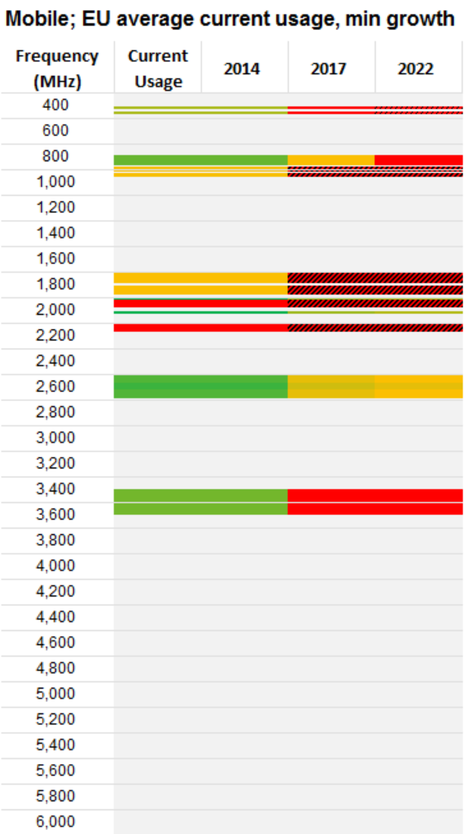
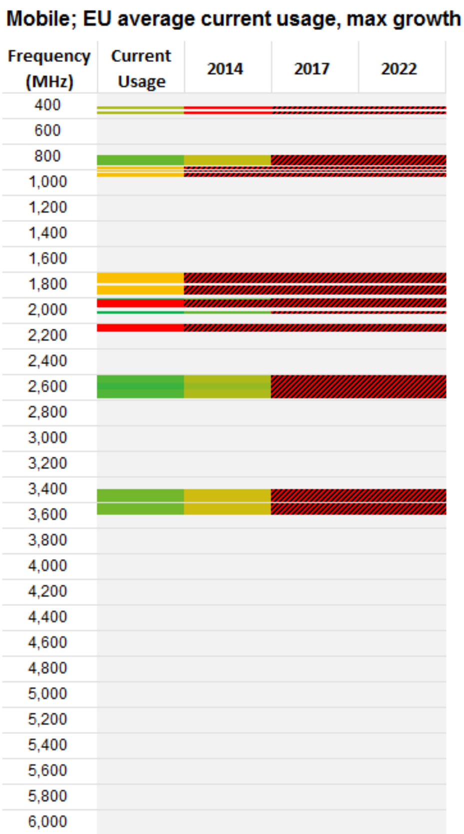


Figure 7.11: Mobile: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]



Differences across countries

In general, future demand for spectrum usage for mobile in the eight focus countries seems to be quite similar, as shown in Figure 7.12 below. However, demand for the 2500–2690 MHz band differs significantly by country, and in Sweden and in some blocks in Germany future usage may exceed supply. There seems to be unused spectrum in the UK, Poland and Czech Republic that could be used to off-set demand for other mobile bands.

In Czech Republic and Poland the 410–430 MHz band has been designated to mobile applications. In addition, in the same countries, mobile currently does not use the 800 MHz band, but we expect that this band will be released as a result of the digital switchover.

Figure 7.12: Mobile: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

Based on the average current usage and the different growth scenarios, there seems to be a clear indication that in all countries average future spectrum usage will exceed 100% of current designated bands, with the exception of some bands as noted above. To be able to cope with this spectrum gap – mainly in the medium and long term – a combination of solutions could be considered such as additional spectrum (700 MHz and 800 MHz, based on current debate), more intensive use of existing spectrum (i.e. increased use of small cells to increase the overall spectral efficiency of an operator's network) and use of new, more spectrally efficient technology together with usage of alternative frequencies and technologies such as Wi-Fi. Spectrum needs for mobile services will depend also on the roll-out of fixed broadband and the way in which broadcasting services are provided.

For wireless data there is an intermediate target in the RSPP to make 1200 MHz of spectrum available for wireless data traffic by 2015.

Some frequency ranges may be attractive in filling this gap. For example, the release of the 700 MHz band for Europe is recognised in the objectives of the EU's RSPP which was adopted by the European Parliament in February 2012, and which draws heavily on the EU's Digital Agenda targets. Although spectrum in the 700 MHz band might possibly be released in the longer term, it needs to be harmonized and is currently designated to broadcasting. Based on this review, other frequencies such as 410–430 MHz might be also considered, as shown by the example of the Czech Republic (although the feasibility of this approach in other countries will require additional research).

In Poland and Czech Republic the designation of the 800 MHz band to mobile services, as has been done in other EU countries, may decrease the gap in the frequencies below 1 GHz in those two countries.

In the long term, another way to decrease the usage of spectrum designated for mobile may be to increase the amount of data traffic from smartphones that is routed via Wi-Fi networks using the 5 GHz band, which is lightly used.

Other bands being considered for public mobile at an international level through the ITU-R and equipment standards bodies are: 450–470 MHz, 2300–2400 MHz and 3400–3600 MHz. A draft opinion published from the RSPG proposes the following bands for mobile services: 470–790 MHz, 1300–1518 MHz, 1800–1900 MHz, 1980–2010 MHz, 2170–2200 MHz, 2.3–2.4 GHz and 3.8–4.2 GHz.

Some European governments have already announced the release of public-sector spectrum for use by commercial services. In the UK government's 'Spending Review' in March 2011 the government announced its intention to release at least 500 MHz of public-sector spectrum below 5 GHz by 2020. The release is intended to make this spectrum available for commercial users, mainly for mobile use.

Sub-1 GHz spectrum is preferred by operators because it propagates further and penetrates buildings better than higher frequencies. It is therefore ideal for deploying wide-area mobile coverage relatively quickly, including for in-building use. On the other hand, bands below about 500 MHz are inherently limited by bandwidth and congested with narrowband services. Bands above 1 GHz are suitable for delivering very high data speeds in areas where capacity is particularly constrained.

7.4 Defence systems (Defence)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

The Defence category encompasses a very broad range of technologies and spectrum uses, and includes demand for all systems that are used by the defence sector. In some cases, these systems will use spectrum bands managed by the military; in others, commercial or other privately held spectrum bands may be used. In addition, it should be noted that, in most Member States, many military bands are shared with other civilian uses, and advances such as dynamic or shared spectrum access could lead to more efficient spectrum use in the future, both within the defence sector and across sectors.

Current spectrum usage

Spectrum usage for defence is high due to the huge diversity that exists within military applications. Defence spectrum is often shared with other uses; for example, in the UK some of the bands designated for use by defence are shared with PMSE and PPDR. This arrangement allows defence to have access to the spectrum when required, but at the same time allows other users to use the spectrum, either in specific geographical locations or on the understanding that there may be some interference from the military uses.

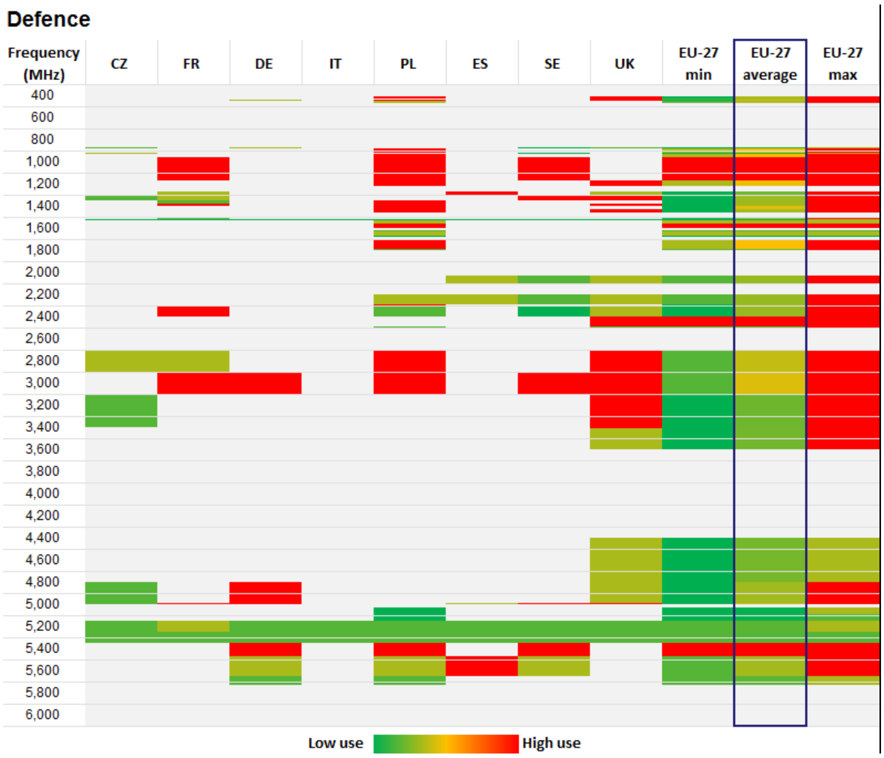


Figure 7.13: Current average usage by Defence for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

Key factors driving spectrum usage

As discussed in Sections 5 and 6, future demand for spectrum for defence will be driven primarily by the following four factors:

- **Growth in activity in the defence sector** – The defence sector is increasingly active due to a rising need for military action in different areas of the world. Despite military forces operating in smaller groups, the use of highly sophisticated equipment makes for a continuous increase in spectrum usage demand.

- **Growth in the number of connected devices and in the amount of information exchanged** – Modern military operations require an enhanced level of connectivity between a proliferating number of devices, which in turn demand increasing amounts of bandwidth. For example, it is envisaged that the UK's "Network Enabled Capability for Close Combat" project will operate at up to 6Mbit/s, a 150-fold increase with respect to today's standards (40kbit/s).[158]

- **Development and take-up of unmanned aeronautical systems (UAS)** – These developments will occur for both segregated and unsegregated airspace. The operation of UAS requires both line-of-sight and beyond-line-of-sight communications, demanding the uninterrupted use of a large amount of bandwidth across a diverse set of geographies. Overall, demand for spectrum usage is expected to increase in the medium to long term.

158 NATO/EDA submissions.

- **Increase in use of satellite and civil and government assets** – Overall, spectrum demand is expected to increase significantly as the military require the ability to obtain surveillance and reconnaissance information from forward areas using satellite communications, Earth observation, integrated services routers (ISRs) and positioning tools, employing a mixture of both secured governmental and commercial assets.

Future demand for spectrum usage

The demand for future spectrum usage for defence applications is expected to increase mainly in the medium and long term. However this is balanced by the holdings that the defence sector has, and technology improvement. The view of NATO and the EDA is that it is unrealistic for defence to require more spectrum, but important to protect existing designations. We expect that technology improvements and efficiencies will support the increased demand within the designated spectrum.

Figure 7.14: Defence: average current spectrum usage in the EU-27: minimum growth scenario [Source: Analysys Mason, 2013]

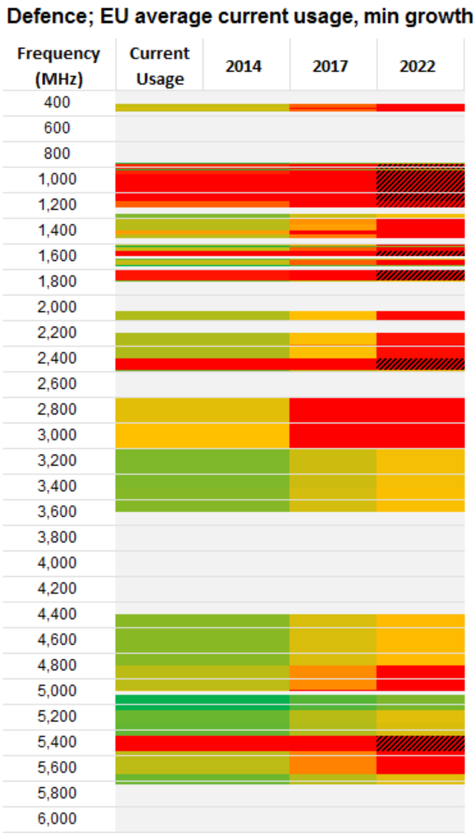
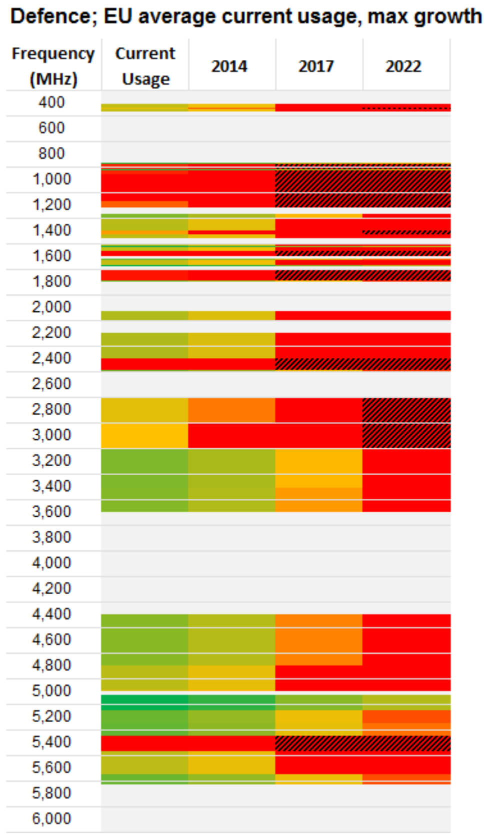


Figure 7.15: Defence: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]



Differences across countries

There are some variations between countries, and in some (such as Italy) there is almost no data available. There is no NATO harmonised spectrum above 400 MHz (significant spectrum below 400 MHz is harmonised). However where spectrum is used for radar and aeronautical applications, coordination across borders is necessary.

Figure 7.16: Defence: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

There is a significant additional demand for the defence sector in the medium to long term, with a more moderate demand in the short term. The view of the sector is that this increase in demand can be managed within the currently used designations, as long as these are protected. The sector is working towards the use of new and enhanced technology that will help to decrease the required bandwidth and increase spectrum efficiency. Some European governments have announced plans to release defence spectrum and offer this for alternative uses on a shorter-term, shared basis.

7.5 Fixed links (Fixed)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

Currently, fixed services use spectrum in frequencies above 1 GHz, namely 1350–1400 MHz, 1427–1452 MHz, 1492–1525 MHz, 1700–1710 MHz, 2025–2110 MHz, 2200–2290 MHz, 3800–4200 MHz and 5925–6425 MHz. In some countries, some of these frequencies are shared with other applications such as PMR and PMSE.

Current spectrum usage

Current spectrum usage by fixed links varies widely across the eight focus countries, as shown in Figure 7.17. In the Czech Republic and Germany, usage of the designated bands for fixed links is high (75–100% of the designated band), while in the other six focus countries usage is in the mid-range (35–75% of the designated band).

Figure 7.17: Current average usage by fixed links for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

Key factors driving spectrum usage

As discussed in Sections 5 and 6, future demand for spectrum for fixed links is expected to be driven primarily by the following factors:

- **Demand for higher-frequency links** – The increasing demand for bandwidth is leading to the migration to higher-frequency links (over 6 GHz), which offer greater capacity. Data shows that between 1997 and 2010, the number of fixed links operating in bands above 6 GHz substantially increased, and we expect this trend to continue, leading to a decrease in demand for spectrum below 6 GHz.

- **Microwave-to-fibre substitution** – The expected explosion in mobile data traffic will drive an increase in both the number of mobile base stations and the traffic per base station in the short, medium and long term. This translates into a growing need for high-bandwidth backhaul links from base stations to transport networks. These connections can be either microwave links or fibre links, though where possible or viable, operators usually prefer to use fibre links as these have lower maintenance costs and greater capacity. This trend would translate into lower demand for spectrum for fixed links.

Future demand for spectrum usage

The demand for future spectrum usage by fixed services will decrease, mainly in the medium term, and we do not expect a significant difference between the minimum and the maximum growth scenarios:

- **Short term (2014)** – Spectrum usage is expected to be similar to the current situation. Most of the bands present a medium usage (35%–75% of designated band), except for the 1350–1400 MHz band which has high usage (75%–100% of designated band).

- **Medium term (2017)** – Spectrum usage is likely to decrease in the medium term, due mainly to the use of fibre, or links with higher frequencies. Most of the bands will present a low usage scenario (0%–35% of designated band), again with the exception of the 1350–1400 MHz band which will exhibit medium usage (50%–75% of designated band).

- **Long term (2022)** – Many cellular operators have adopted strategies to invest in fibre networks for high-capacity links. Even so, radio links will still be used for backhaul in rural areas, or to provide alternative routing and back-up capacity. There will also be an increase in the use of fixed links to provide backhaul to small cells, which are becoming more prevalent. Overall, therefore, in the long term we expect spectrum usage to be similar to the medium term.

Figure 7.18: Fixed links: average current spectrum usage in the EU-27: minimum growth scenario [Source: Analysys Mason, 2013]

Figure 7.19: Fixed links: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]

Differences across countries

The demand for future spectrum usage in 2022 in the eight studied countries is quite similar. Most present a medium usage scenario (50%–75% of designated band). The main differences between countries are that:

- Czech Republic and Germany present a higher usage in the 3800–4200 MHz band
- Spain, Poland and Sweden have lower usage in all bands.

Figure 7.20: Fixed links: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

Based on average current usage and the different growth scenarios, there seems to be a clear indication that average future spectrum usage will still be below 50%–75% of current designated bands. Therefore, we believe that available spectrum could be shared, or used to help accommodate future spectrum usage demand from other services like WLAN (subject to viability).

It is important to note that fixed microwave links can be deployed across a wide range of frequencies, though the ideal frequency will depend on the exact requirement that is being met. To limit congestion in the frequency bands below 6 GHz, microwave links may be moved to higher bands (above 6 GHz) which are popular for high-capacity and shorter-length links. Congestion, while still possible in these higher-frequency bands, is less of a problem than in the lower bands, due to higher re-use factors. CEPT has already considered the possibility of migrating low-capacity, long-range fixed links still operating in the region of 1400 MHz into frequency bands higher than 6 GHz.

More recently, frequency bands in the 60–80 GHz range are beginning to be used for very short, high-bandwidth links (sometimes referred to as ‘gigabit wireless’ because the bandwidth may be 1Gbit/s or more). It is of interest that the 60 GHz band is licence-exempt in the UK and in other countries.

Fixed links are ideally suited to sharing spectrum with other services. For example, in UK, in the 23 GHz band, fixed links share the spectrum with radio astronomy – this sharing is managed through the establishment of pre-defined co-ordination zones around radio astronomy sites. This approach could be adopted to avoid interference into other services where the usage is in a defined geographical area.

7.6 Intelligent transport systems (ITS)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

ITS applications currently operate in the 5795–5815 MHz and 5875–5905 MHz bands, which are shared with other services.

Current spectrum usage

There is a lack of information relating to current spectrum usage by ITS in the eight focus countries: data seems to be only available for the UK, France and the Czech Republic. Usage is low in the Czech Republic (0%–35% of the designated band), and medium in France and the UK (35%–50% of the designated band). Across the EU-27, average usage of these bands is usually low; only the maximum growth scenario for the EU-27 shows high usage (75%–100% of the designated band).

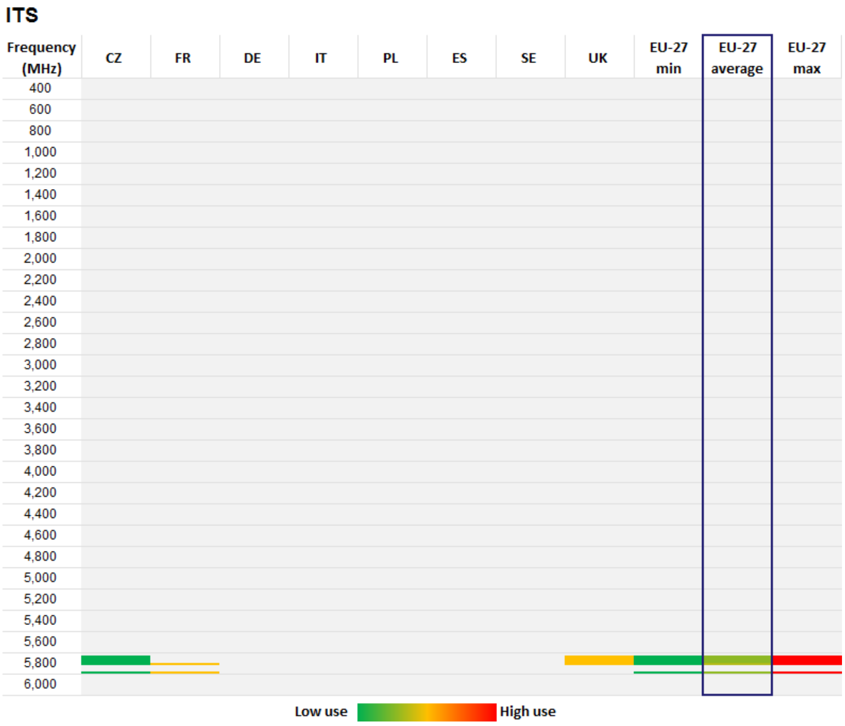


Figure 7.21: Current average usage by ITS for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

Key factors driving spectrum usage

As discussed in Sections 5 and 6, future demand for spectrum for ITS is expected to be driven primarily by the introduction and take-up of new applications for traffic and freight management, and closer integration of vehicles into the transport infrastructure to ensure road safety and security.

Future demand for spectrum usage

It is expected that future usage of spectrum for ITS will increase due to the take-up of these new applications, though there are differences between the estimates from various organisations, as to the exact spectrum requirements of future ITS applications within the 5.9 GHz band. ETSI estimates that 75 MHz will be required,[159] while in 2007 CEPT estimated 50–70 MHz,[160] amending this in 2008 to 30–50 MHz.[161]

Figure 7.22 and Figure 7.23 below show the potential future spectrum usage for the minimum and maximum growth scenarios, based on an average value for current spectrum usage. As can be seen it is only in the maximum growth scenario that a usage exceeding designation may be reached by 2022. For other scenarios, such as maximum growth until 2017 and minimum growth until 2022, usage will be within the designation in the bands considered.

Figure 7.22: ITS: average current spectrum usage in the EU-27, minimum growth scenario [Source: Analysys Mason, 2013]

Figure 7.23: ITS: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]

159 System Reference Document ETSI TR102 492.

160 CEPT Report 20 (21 December 2007).

161 ECC Decision of 14 March 2008 on the harmonised use of the 5875–5925MHz frequency band for Intelligent Transport Systems (ITS).

Differences across countries

Given the lack of information for the majority of the focus countries, it is difficult to make any direct statement about the differences between them. However, Figure 7.24 below shows that usage in the Czech Republic seems moderate by 2022 (based on average current usage and average growth), while in the same timeframe France and the UK seem to have a usage which exceeds designation.

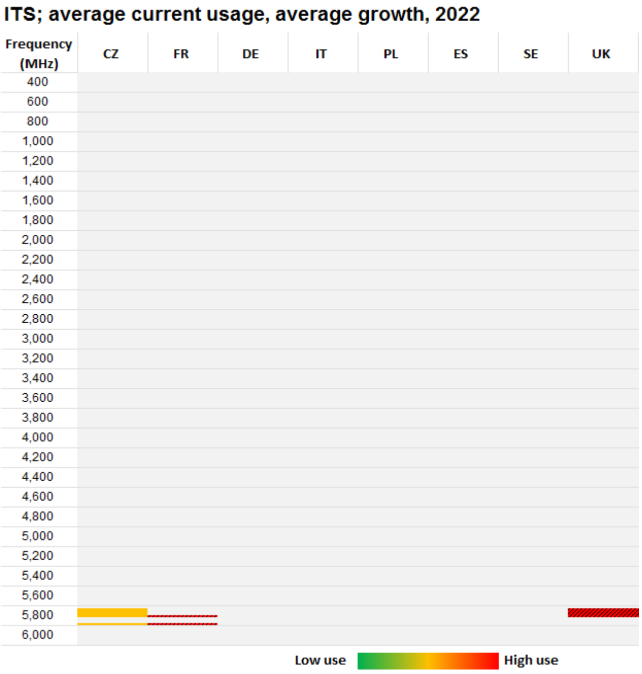


Figure 7.24: ITS: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

Based on the information available, the key ITS band at 5.9 GHz will be adequate for the growth of ITS applications and usage for all but a few cases (namely the UK by 2022). It should be noted, however, that it is difficult to come to definitive conclusions due to the lack of information for a majority of the focus countries, and the differences in future estimates (ranging from 30 MHz to 75 MHz in the 5.9 GHz band) made by various organisations.

There are discussions about designating an additional 20 MHz of spectrum in the 5905–5925 MHz band, which would go some way to decreasing the congestion, though it is still less than the lowest estimate of ITS spectrum requirements (30 MHz). Another possibility would be the use of the 63 GHz band.

7.7 Meteorology (MET)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

Currently, the relevant frequency bands of interest to Meteorology are 2700–2900 , 1350– 5650 MHz, 5350–5650 MHz and a large number of bands above 6 GHz. In some cases the sub-6 GHz bands are shared with other application categories.

Current spectrum usage

Current spectrum usage by this category seems to vary considerably not only between bands but also between countries. As shown in Figure 7.25 usage of the 5350–5450 MHz band is consistently high, not only in the eight focus countries but also throughout the EU-27 as a whole. In contrast, usage of the 5450–5650 MHz band is for the most part low throughout the EU-27, with the exception of the UK and Spain where high usage is seen.

Figure 7.25: Current average usage by Meteorology for eight countries and EU-27 min, max and average[Source: Analysys Mason, 2013; WIK Study, 2012]]

Key factors driving spectrum usage

Many meteorological activities are organised at a global level, and therefore spectrum-related issues must be considered globally since unilateral European decisions might have worldwide impact on use of frequencies and on meteorological measurements. For this reason it is difficult to identify the main key drivers from the technology, consumers or communities point of view. However, in Sections 5 and 6, we did identify a number of drivers, concluding that they will not have a material impact on the demand for future spectrum usage, at least during the time horizon of the study (up to 2022). In support of this, stakeholders have confirmed that they will not need additional (designated) spectrum, although the actual usage of the spectrum is as always uncertain.

Future demand for spectrum usage

As can be seen in Figure 7.26 and Figure 7.27, spectrum usage for meteorology remains constant across all three time frames (2014, 2017 and 2022), as well as remaining constant between the minimum and maximum growth scenarios.

Figure 7.26: Meteorology: average current spectrum usage in the EU-27: minimum growth scenario [Source: Analysys Mason, 2013]

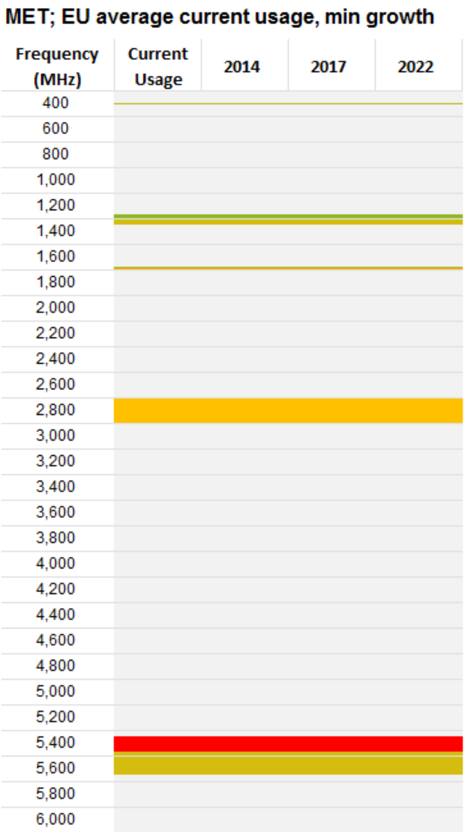
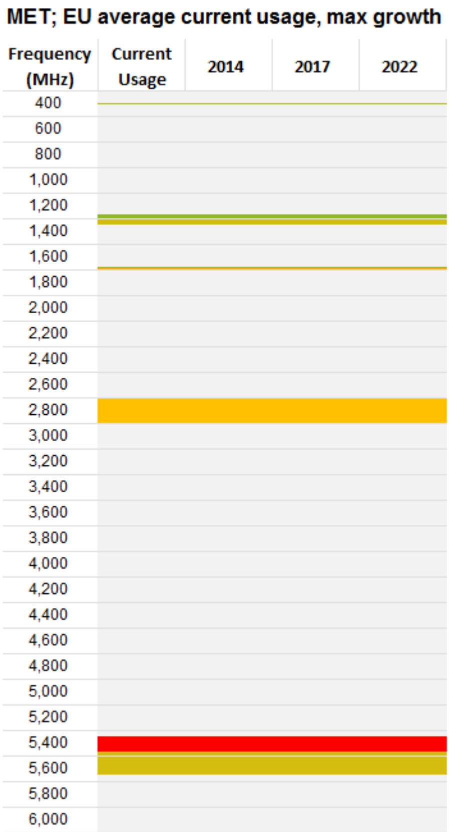


Figure 7.27: Meteorology: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]



Differences across countries

Due to the relatively unchanging nature of the spectrum usage for this category, the existing variations between countries will remain the same in the future. As shown in Figure 7.28 below there will still be high usage of the 5350–5450 MHz band in all focus countries. The UK and Spain show high usage of the 5450–5650 MHz band, but usage of this band is low in all of the other countries.

Figure 7.28: Meteorology: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

The main conclusion for this usage category is that there seems to be limited pressure on future spectrum usage. Stakeholders did, though, stress the importance of ensuring that meteorology maintains the spectrum designations that it already possesses, due to the specific requirements of this use as well as its sensitivity to interference. In many cases, the choice of spectrum band used for meteorological services is determined by very specific physical requirements, and it is likely to be difficult to find alternative frequency bands for many meteorological uses.

7.8 Private mobile radio/public access mobile radio (PMR/PAMR)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

PMR includes not only the underlying radio network of base stations, but also the handheld, console or mobile radio devices which require the use of licensed spectrum. This category is closely linked to the PPDR category, as many PPDR communications systems involve applications of PMR/PAMR technologies. PMR is also closely linked to usage for utilities and transportation. In the case of utilities, as well as existing use there are new applications for smart grids and smart metering. In transportation, PMR is a vital tool for railways (GSM-R uses dedicated spectrum at 800 MHz). Both these two user communities are considered under the PMR heading, as well as general PMR, which can also be referred to as business radio.

We consider the demand for new spectrum for PMR and PAMR in terms of three categories:

- general PMR/PAMR (business radio)
- smart grid and smart metering
- ECTS and GSM-R replacement.

Current spectrum usage

PMR uses lower-frequency spectrum as this allows coverage of larger areas from each radio site. Typically, the spectrum is of relatively low value, as there is no direct financial benefit from the spectrum – it is used as a tool to allow users to operate more effectively and safely.

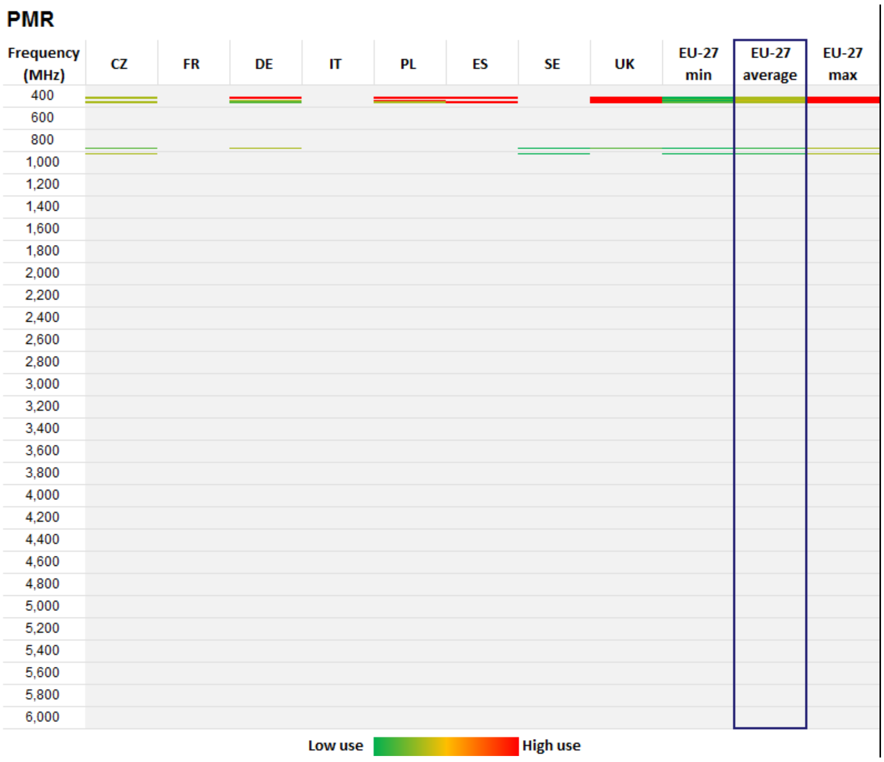


Figure 7.29: Current average usage by PMR for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

Key factors driving spectrum usage

Overall, there is very modest demand for new spectrum in the PMR/PAMR sector. In the following subsections we describe the drivers for spectrum demand for each of the three PMR/PAMR categories identified above.

► *General PMR/PAMR (business radio)*

- Data from the industry shows that there is a steady growth in the number of radio units being sold into the general PMR sector.[162] Growth in PMR equipment worldwide is forecast to increase by 25% between 2012 and 2020, to reach over 50 million units (the EU accounts for some 33% of this global base). However, compared with commercial networks the number of terminals is small, and growth is moderate. For PAMR there is actually a reduction in the number of systems in use, as users are migrating to commercial mobile networks.

- Improvements in spectrum efficiency with digital radio should in time reduce spectrum needs. The experience of early adopters is that they still use the same amount of spectrum, but enjoy benefits such as packet data and other applications. In time, however, as more users move to digital technology, a spectrum efficiency benefit should emerge.

[162] Source IMS Research, 2013

- There is a two-way churn between PMR and commercial mobile networks. On the one hand, PMR users are migrating onto commercial networks for a number of reasons, including the cost of PMR equipment, the fact that PMR coverage does not meet their needs, and features such as smartphones and high data speeds that are more readily available on mobile networks.

  At the same time, some users on commercial networks are moving to PMR for reasons such as: PMR provides good reliable indoor coverage (which may be of value in a conference centre or arena, for example); PMR enables very fast responses from users (such as staff in a large hotel or casino); and PMR offers low operating costs.

  On balance, more users migrate from PMR onto commercial networks than vice versa, and this will result in a slightly reduced demand for PMR in the long term

► *Utilities (smart grids and smart metering)*

There is a clear demand for PMR spectrum for smart grid applications, which are critical real-time applications. In contrast, smart metering applications are less critical, and while they can use PMR (with a technology commonly called long range radio), there are many other alternative bearers such as commercial networks, licence-exempt mesh, satellite and power line communications (PLC). The key demand drivers for smart grid and smart metering are:

- Energy policies, climate change and environmental regulation: EU policy and Directives have set climate and energy targets for 2020, known as the '20-20-20' targets. These have a direct impact on all utilities, but especially power utilities, which need to use more renewable energy sources, and more carefully control the distribution of energy: this will be achieved via smart grid applications. There must also be more precise matching of demand for power to generation capability, and better understanding of consumer requirements: this will be achieved via smart metering.

- Energy resources are reducing and market forces are driving energy costs upwards. At the same time, consumers are more reliant on power, and more demanding. This situation can result in power outages, which are costly for utility companies: it is estimated, for example, that the cost of power outages in the USA is USD104–164 billion per annum.[163] Utilities therefore have to be more efficient, and match supply more closely with demand, operating with less spare capacity, and providing higher availability; this requires more complex communications, some of which have to be wireless and PMR-based.

- The sources are inputs from EUTC, ESB (Irish Electricity) and Alliander (Netherlands Utility) into our project following the first workshop in Brussels. There is a file in the folder called From EC.doc which has the inputs. Main source is the EUTC (search for JRC) which has further sources and papers within the input.

[163] Source: stakeholder workshops.

- Use of alternative networks. Although utilities do utilise commercial networks for some uses, the critical nature of smart grid applications makes these networks generally unsuitable: in a large power outage, the commercial sites would fail quickly, at the very time when communications are most required to restore the network. Smart metering, on the other hand, is an application where non PMR-type communications can be used, although quality of service and security might be an issue (networks are at risk of cyber attack, and security is important). Potential alternative networks include: commercial networks (GPRS or 3G), mesh networks (using lightly licenced or licence-exempt spectrum such as 870–876 MHz), or power line communications (which are outside the scope of this study). Since the choice of bearers for smart metering is driven by commercial drivers as much as by technical solutions, there is no quantifiable impact on spectrum usage from alternative networks.

► *ECTS and GSM-R*

GSM-R is mandatory for use by mainline railways throughout Europe, and is in widespread use, both for voice communications and as a bearer for ECTS. Key drivers for spectrum demand are:

- ECTS is a relatively low-bandwidth application that makes use of both passive and active (e.g. GSM-R) elements. The passive elements serve signalling purposes and use HF spectrum outside the scope of this study. Current GSM-R networks are not heavily used, and the increased deployment of ECTS will have only a modest increase on GSM-R spectrum usage.

- GSM is now an old technology, and GSM-R – being a special standard – will not be maintained into the future. It is estimated that it will reach end of life in 2027, and an alternative solution will need to be in place. The deployment of such a solution, whether LTE (as expected) or another solution, will take up to 10 years, and so trials of a new solution will need to commence by 2017. There is insufficient spectrum in the GSM-R bands to run parallel systems during the transition to the new system, so transition spectrum will be required.

Future demand for spectrum usage

- The steady growth of the general PMR sector does not demand additional spectrum.

- The demand for smart grid applications, and the general increase in the spectrum requirements of utilities, will lead to a significant demand for future spectrum in the short, medium and long term. This demand has been quantified by EUTC, which has suggested the following requirements for spectrum:[164]

  — VHF spectrum (50–200 MHz) for resilient voice communications and distribution automation for rural and remote areas [2×1 MHz] – not relevant to this study
  — UHF spectrum (450–470 MHz) for smart grid, SCADA and automation [2×2.5 MHz]

164 These estimates were broadly validated by stakeholders during the workshops, especially ESB (an Irish utility) and Alliander (a Dutch utility).

— lightly regulated or deregulated shared spectrum for smart meters and smart grid [870–876 MHz]
— L-band (1500 MHz) for more data-intensive smart grid, security and point-to-multipoint applications [10 MHz]
— public microwave and satellite bands (1.5–58 GHz) for access to utilities' core fibre networks or strategic resilient backhaul.

- Currently GSM-R has a designated 2×4 MHz of spectrum in the 900 MHz GSM band. There is also a recent designation of 2×3 MHz immediately below the GSM-R band, which is available on a shared national basis. It is unclear what spectrum the replacement solution would require, but if based on LTE it would most likely require at least 2×5 MHz. While the final designation is unclear, it is reasonable to assume a requirement of 2×5 MHz of transition spectrum between 2017 and 2027, as replacement systems are rolled out Europe-wide.

Figure 7.30: PMR: average current spectrum usage in the EU-27: minimum growth scenario [Source: Analysys Mason, 2013]

Figure 7.31: PMR: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]

Differences per country

The demand is very similar across all the focus countries, especially for utilities and GSM-R.

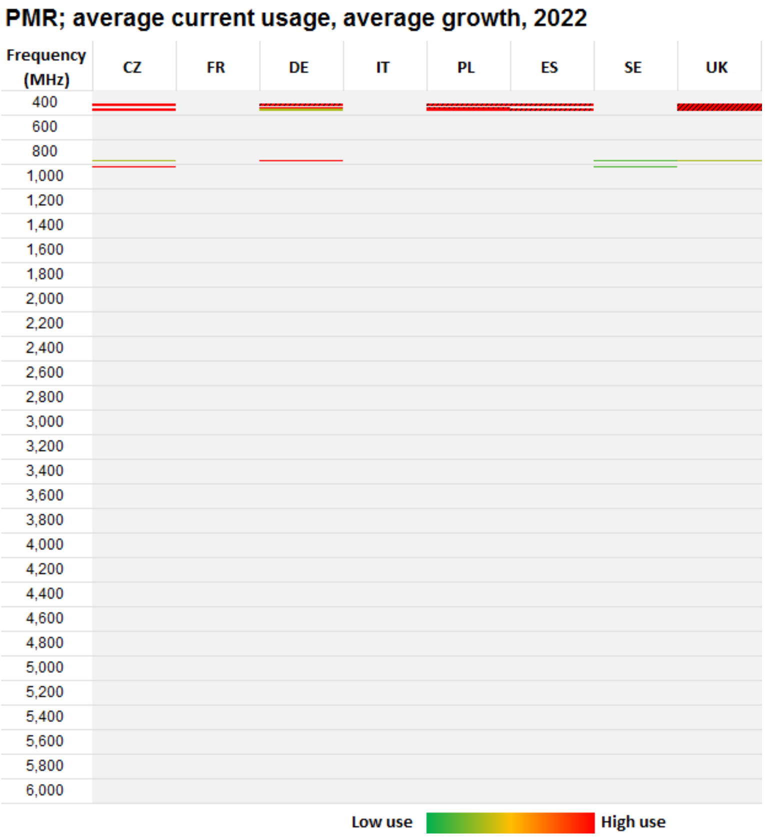


Figure 7.32: PMR: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

The future spectrum demand comes from two sectors: utilities (for smart grid applications) and railways (for GSM-R transition spectrum). The demand from utilities is for the short, medium and long term, and is for:

- UHF spectrum (450–470 MHz) for smart grid, SCADA and automation [2×2.5MHz]
- lightly regulated or deregulated shared spectrum for smart meters and smart grid [870–876 MHz]
- L-band (1500 MHz) for more data-intensive smart grid, security and point-to-multipoint applications [10 MHz].

It is likely that if national utilities have a choice, they would use a combination of bands and technologies, possibly with 870–876 MHz mesh networks in urban environments and UHF in rural environments.

The demand for GSM-R is very specific, and is a need for transition spectrum in the medium and long term to migrate from the existing systems to new systems. Discussions with the industry would be required as to whether railways use the transition spectrum only temporarily, returning eventually to the standard GSM-R band, or stays on the transition spectrum, releasing the current GSM-R band for use by mobile networks once the migration has taken place.

7.9 Programme making and special events (PMSE)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

PMSE uses spectrum mainly in the 470–862 MHz and 3100–3400 MHz bands, as well as some spectrum within the 2025–2400 MHz frequency range; some wireless cameras and video links also operate in frequencies above 6 GHz. Although the use of some PMSE spectrum is concentrated among a small number of users, a significant portion of use is fragmented, and is often shared with other services. Demand for PMSE is localised and time-limited.

Current spectrum usage

Current spectrum usage within the bands designated for PMSE seems to vary across countries. Except in the Czech Republic and Poland (where only 35%–50% of the designated band is in use), the 470–790MHz band is highly used (75%–100%) in the other six focus countries. Across the EU-27, however, average usage of this band is moderate (35%–70% of the designated band).

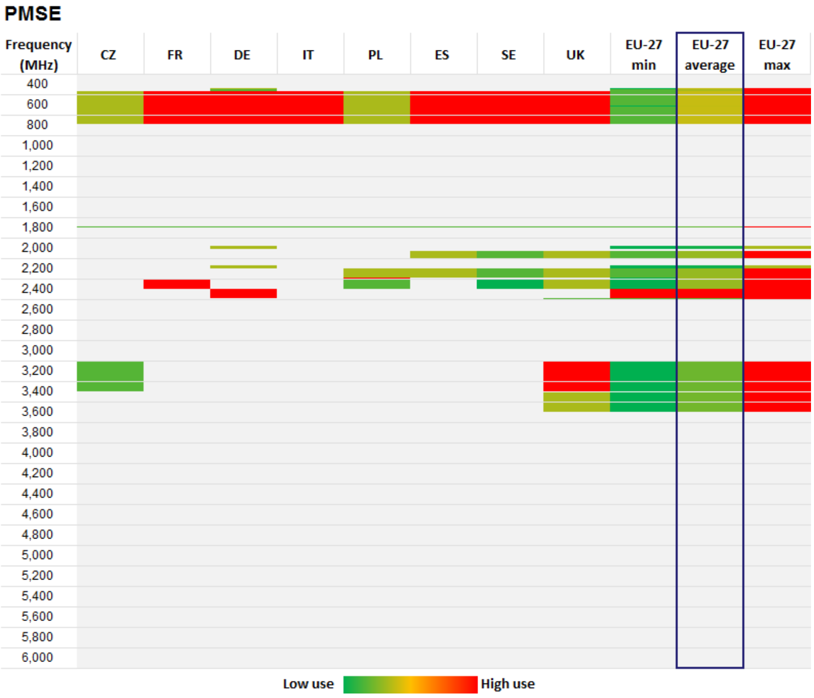


Figure 7.33: Current average usage by PMSE for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

As a result of policy changes in Europe, spectrum in the top part of the UHF band (790–862 MHz) has been re-designated for mobile use and is no longer used for digital TV, nor will it be available for PMSE.

Key factors driving spectrum usage

There are two main drivers for future spectrum usage within this category:

- Increase in the amount of PMSE equipment at each event: Broadcasting programmes and events that require PMSE spectrum are becoming increasingly more complex and technically demanding, and there is a trend to use more and more equipment and therefore an increasing amount of spectrum.
- Adoption of HD and 3D cameras: Due to the increased spectrum demand of these types of cameras, the strong take-up of these technologies will lead to a step increase in spectrum demand in the next ten years.

Future demand for spectrum usage

As described in Sections 5 and 6, the usage of spectrum for PMSE is going to increase. The increase is expected to be mainly in the short term (2014) – thereafter the demand will stay constant during the medium (2017) and long (2022) terms. There will be high usage demand (75%–100% of designation) for the 470–790 MHz band in both the minimum and maximum growth scenarios. We note that as these growth estimates are based upon EU average current usage, demand may well be higher in some, given the differences between countries described above.

The only spectrum that may see usage exceeding 100% of designation (when considering EU-27 average current usage) is the 2400–2500 MHz band. Large amounts of spectrum will have low to moderate usage (35%–75% of designated band), such as the 3100–3600 MHz band as well as 200MHz–2400 MHz (although this may see high usage in the maximum growth scenario). These bands could probably absorb the excess demand in the 2400–2500 MHz band.

Figure 7.34: PMSE: average current spectrum usage in the EU-27, minimum growth scenario [Source: Analysys Mason, 2013]

Figure 7.35: PMSE: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]

Differences across countries

Figure 7.36 below shows the differences between the eight focus countries when considering the average current usage and average growth scenario to 2022. The bands where usage may exceed 100% of designation are 470–790 MHz in all countries except the Czech Republic and Poland; 2300–2400MHz in France; 2400–2500 MHz in Germany; and 3100–3300 MHz in the UK.

Figure 7.36: PMSE: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

Based on average current usage and different growth scenarios, and taking into consideration the differences between countries, there are indications that future PMSE usage may exceed designation in two areas. The first is the 470–790 MHz band; this shows high usage (75%–100% of designation) when considering the EU average current usage and both growth scenarios, and shows greater than 100% usage when considering the focus countries (except for the Czech Republic and the UK). A possible mitigation factor is the advances being made in compression technologies: the industry is working towards improvements that would allow HD equipment to be used within a 10MHz channel.

The second band where usage may exceed designation is the 2400–2500 MHz band, which shows above 100% usage in both minimum and maximum growth scenarios when considering the EU average current usage (though this is only relevant for Germany when considering the focus countries).

As in the case of broadcasting services, the eventual release of the 700 MHz band from DTT to mobile services, as agreed in some countries, will further reduce the number of channels available for PMSE and increase the congestion problem. Certain frequency ranges may be attractive in filling this gap: for example, some governments, such as the UK, are planning to award the 600 MHz spectrum band for broadcasting purposes alongside PMSE. Currently PMSE services make use of white spaces within spectrum used for TV broadcasting, but it is unlikely that such use could continue in the 700 MHz sub-band if that is used for mobile. However, it should be noted that many others bands might have only low to moderate utilisation throughout the period and might be used to alleviate the demand issues. CEPT has recently consulted on the designation of the 1492–1518 MHz band for use by PMSE.

7.10 Public protection, disaster relief (PPDR)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

PPDR mobile communications have generally been based on PMR technologies such as those used in the TETRA or Tetrapol networks used by the majority of police organisations in Europe. Many of these networks use spectrum in the 380–400 MHz band, which is very close to the lower limit of the frequencies covered by this study (400 MHz). Also, in many EU countries PPDR applications use the 380–400 MHz band released from NATO. We note that these uses have not been captured in this study, which partially explains the discrepancies observed across countries and the lack of data regarding current spectrum usage for some countries.

Spectrum in the 3–4GHz range as well as 5 GHz SRD spectrum is also available in some countries for wideband air-to-ground video systems (such as Heli-Tele), but use of these bands for this type of application is not widespread.

Current spectrum usage

PPDR spectrum in 380–385MHz paired with 390–395 MHz is highly used (as shown in the figure below), mostly in the TETRA or Tetrapol police networks. Spectrum below 1 GHz is considered to be optimum for PPDR applications, due to its better propagation characteristics, and because it allows to cover larger areas from a single cell site, thus minimising infrastructure costs.

Figure 7.37: Current average usage by PPDR for eight countries and EU-27 min, max and average [Source: Analysys Mason; WIK Study]

Key factors driving spectrum usage

There are two drivers for future PPDR spectrum usage:

- The main driver is the expected large increase in demand for data-rich applications. This is in line with general societal demands for access to data on the move, and applies to PPDR as well. These applications include the provision of more situational awareness, where the control room is aware of what is happening to an officer, and passing information to officers so they are aware of their environment. There is also an increasing need for video from and to incidents and planned events.

- A second driver is a general increase in PPDR activity, principally as a consequence of terrorism and political activism. This is resulting in shortage of spectrum at major events, and in border areas where neighbouring countries have to share the common spectrum designation.

Future demand for spectrum usage

At present demand is constrained by a lack of suitable spectrum for mobile broadband applications. The demand for data-rich applications has originated with users, and has been captured by the Radio Communication Expert Group of the Law Enforcement Working Party (LEWP-RCEG). The TETRA and Critical Communications Association (TCCA) has formed the Critical Communications Broadband Group (TCCA CCBG), which is looking at developing mobile broadband standards for critical communications, and is attended by organisations in the fields of public safety, utilities and UIC (railways). LEWP-RCEG has worked with ETSI TC TETRA WG4 on identifying the bandwidth needs for the required services, and has developed a number of scenarios in order to quantify typical data bandwidth requirements. This in turn has been an input into CEPT Working Group FM Project Team 49, which is looking at broadband spectrum for PPDR. The working group has recently issued a draft report (ECC 199) for consultation.[165] This report identifies a minimum requirement of 2×10 MHz of spectrum for mobile broadband for PPDR. It notes that this requirement does not include voice, air-ground-air (AGA), direct mode operations (DMO) or ad-hoc networks. Voice is believed to require a further 2×3.2 MHz. The requirement for AGA was not quantified, but an input from the Ministry of the Interior in Germany suggests a base requirement of 15 MHz, with a further 7.5 MHz for localised video links. In parallel, there is an identified demand at the European level for more spectrum within the tuning range of existing systems for voice and wideband data applications.

If, as a consequence of WRC15, spectrum is made available for dedicated PPDR mobile broadband, users will be working with regulators to plan for networks, which will most likely be required from 2018 onwards.

Figure 7.38: PPDR: average current spectrum usage in the EU-27: minimum growth scenario [Source: Analysys Mason, 2013]

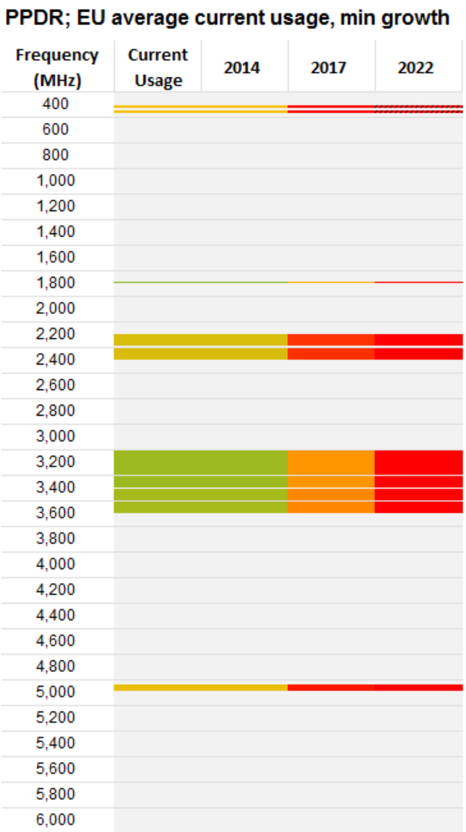
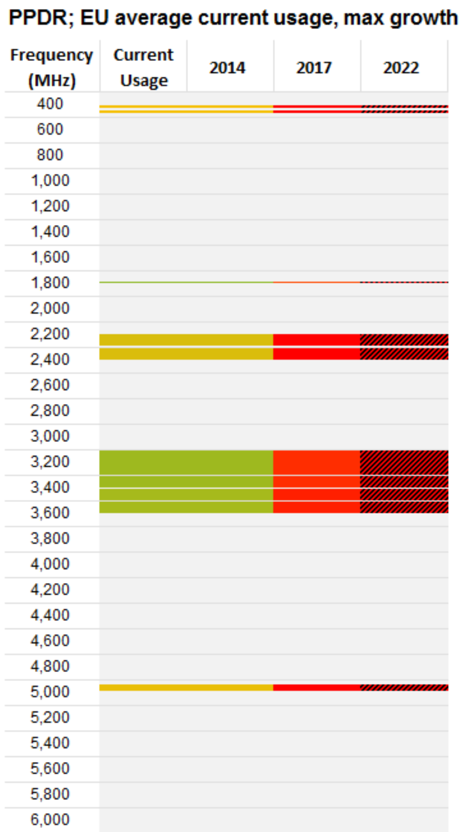


Figure 7.39: PPDR: average current spectrum usage in the EU-27: maximum growth scenario [Source: Analysys Mason, 2013]



165 http://www.cept.org/ecc/groups/ecc/wg-fm/fm-49/page/the-public-consultation-of-the-draft-ecc-report-199-is-open

Differences across countries

The usage per country is very variable, though much of this variability is artificial and due to the 400 MHz lower sampling limit. All Western European countries use 380–400 MHz for voice services, and higher spectrum bands are often used for air-ground video applications.

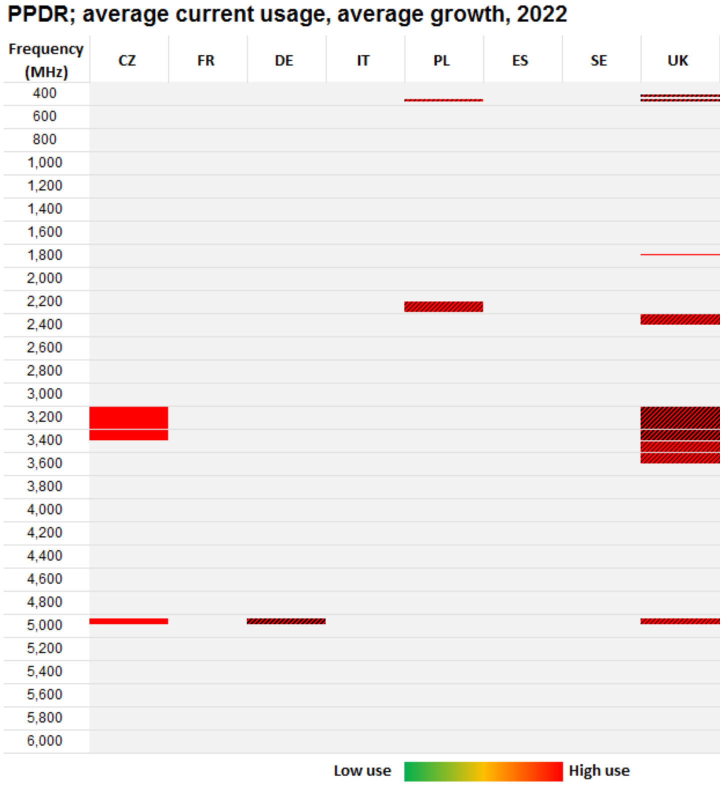


Figure 7.40: PPDR: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

There is a clear demand for mobile broadband services, and a minimum requirement for 2×10 MHz of sub-1 GHz spectrum has been recognised.

Currently many PPDR organisations take data services from public networks, alongside voice and narrowband networks used for critical applications. These data networks do not, however, provide truly mission-critical services. An example of an organisation making use of public networks is Astrid, a Belgium PPDR operator which is arranging an MVNO which will allow it to access any of the national operators in Belgium, using the multiple networks to improve coverage and availability. The MVNO will operate alongside the existing network and Astrid ultimately may migrate to a hybrid commercial and private network model.

The most likely spectrum for a harmonised 2×10 MHz band will be from the 700 MHz digital dividend. There may also be some opportunities for low-frequency 400 MHz spectrum, but it would be more difficult to achieve harmonised spectrum in this case.

Many air-ground applications could be in spectrum above 2 GHz, with designations on a national basis, but with coordination.

7.11 Radio astronomy (Science)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

The main spectrum application within the category of Science is that of radio astronomy, which across the EU uses various bands, the main ones being within the 3100–3400 MHz and 4800–5400 MHz bands. This spectrum is shared with other applications, but it should be noted that due to the passive and sensitive nature of this application it is very susceptible to interference.

Current spectrum usage

As can be seen in Figure 7.41 below, the usage of spectrum by science applications varies across the eight countries and the EU-27 as a whole. The amount of information available also varies between countries. Considering the EU-27, under the average usage scenario the majority of bands show moderate usage, whereas the minimum and maximum scenarios show low and high usage respectively. This shows that there is a high degree of variance within the EU-27 and so the growth rates assumed will have quite varying effects.

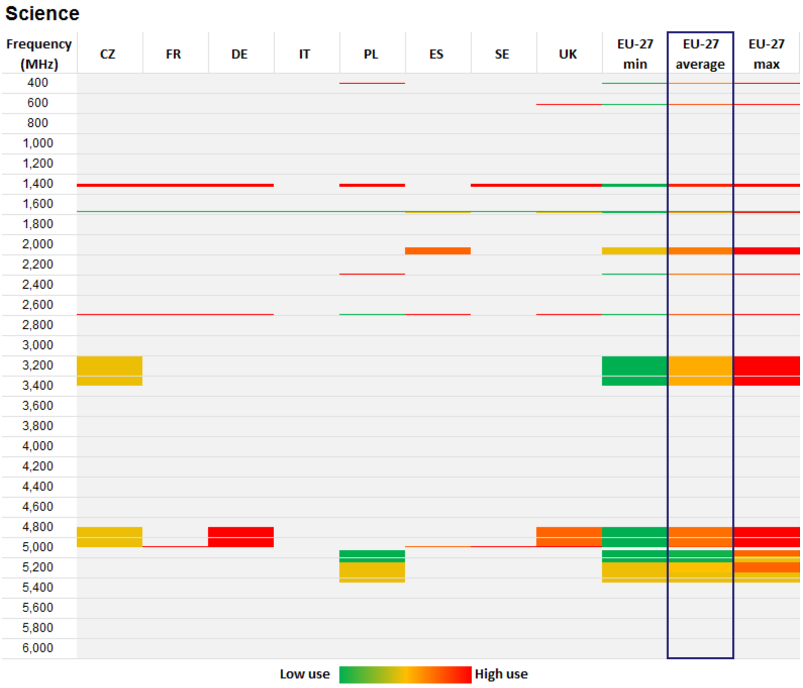


Figure 7.41: Current average usage by Science for eight countries and EU minimum, maximum and average [Source: Analysys Mason, 2013; WIK Study,2012]

Key drivers for future spectrum usage

In Sections 5 and 6, we identified several drivers for future spectrum usage demand, but we estimate that they will not have a material impact, at least during the time horizon of the study (up to 2022). However, the spectrum designation to science should be kept and protected, and some blocks of spectrum need to be adequately protected from harmful interference – in particular, attention should be given to which services are allowed to operate in adjacent bands. Stakeholders have forecast that they will not need additional designated spectrum, although the actual usage of the spectrum is as always uncertain.

Future spectrum usage demand

The main consideration regarding future spectrum usage by science is simply to maintain current spectrum designations. There is therefore no change in usage across the three time periods, as can be seen in Figure 7.42 and Figure 7.43 below.

Figure 7.42: Science: average current spectrum usage in the EU-27, minimum growth scenario [Source: Analysys Mason, 2013]

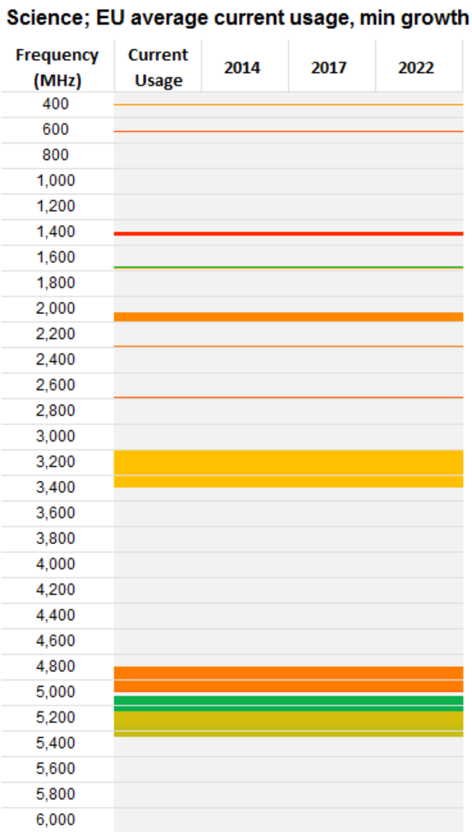
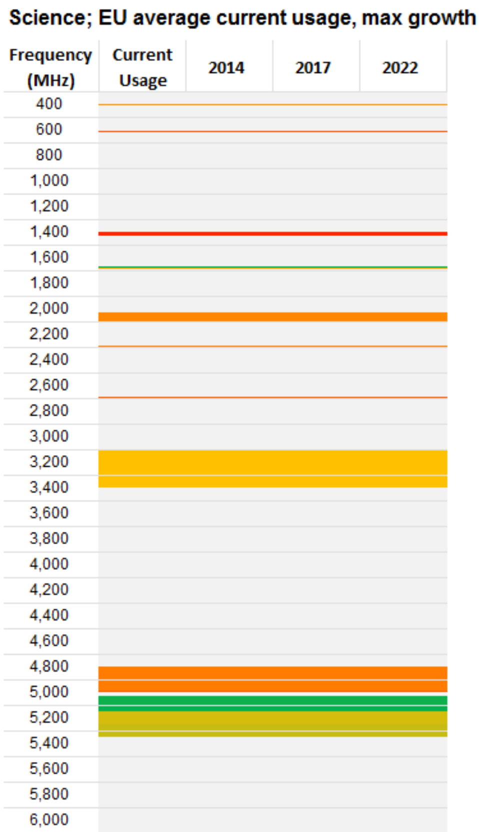


Figure 7.43: Science: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]



Differences per country

Given that there is no growth in usage of spectrum for science, the patterns of usage for each country will remain the same as at present (see Figure 7.44 below).

Figure 7.44: Science: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

There seems to be limited pressure for growth of spectrum usage for science applications. Stakeholders did, however, highlight the importance of ensuring that this application maintains the spectrum designations that it already possesses, due to the specific characteristics of its use as well as its sensitivity to interference.

7.12 Satellite systems (Satellite)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

Within the range of frequencies being considered in this study (400–6000 MHz), satellite systems operate in the L-band (~1–2 GHz) the S-band (2–3 GHz) and the C-band (3–7 GHz). The S-band is also designated for scientific uses; that use was covered in Section 7.11.

Current spectrum usage

Current spectrum use for satellite applications seems to be very varied across the EU. In the main spectrum designated for satellite use (3600–4200 MHz) the usage (where there is information) is low in Poland, Spain and the EU-27 minimum; moderate in France, Italy and the EU-27 average; and high in Germany, the Czech Republic and the EU-27 maximum. This heterogeneity is also seen (but to a slightly lesser extent) in the other bands designated to satellite applications, such as the bands within the 2100–2300 MHz range.

The spectrum designations in the 1500–1700 MHz range show homogenous, moderate-to-high usage across not only in the eight countries but also across the EU-27 as a whole.

Designations in the 2000–2300 MHz range display low-to-moderate usage within the eight countries. The EU-27 average also shows moderate usage, though in this part of the spectrum the maximum usage across the EU-27 is seen to be high.

There is also a small portion of spectrum (435–438 MHz) that is designated to *amateur* satellite applications. Where there is available information, this exhibits moderate-to-high usage.

Figure 7.45: Current average usage by Satellite for eight countries and EU-27 min, max and average *[Source: Analysys Mason, 2013 WIK Study,2012]*

For consistency with the other categories, our assessment of current spectrum use by satellite is based on the WIK Study. However, comparing the eight focus countries, we believe there are some inaccuracies in the study. For example in Czech Republic the 3.8 GHz band is not used for satellite services.

Key drivers for future spectrum usage

The key driver for future spectrum usage by satellite applications, as mentioned in Sections 5 and 6, is mainly the increasing demand for the S-band and the C-band. In 2009, the EC awarded Solaris and Inmarsat a part of the S-band spectrum. Given that the number of terminals for mobile satellite services (MSS) is expected to double over the next ten years and that the traffic per terminal will also increase, demand for the S-band is expected to surge.

The C-band is much valued due to its superior propagation characteristics (allowing very wide coverage) and less susceptibility to rainfall and humidity (enabling signal resiliency). Demand is being driven by the increasing bandwidth required for backhaul and trunking services, professional services, and the continuously increasing bitrates used for video distribution.

The European satellite navigation constellation (Galileo) will use ~120 MHz of spectrum in the L-band; this has, however, already been designated and so is included within the current usage. To date, four satellites have been launched. As the deployment continues, the usage of this designated spectrum will increase, although this is only likely to happen after 2022.

Future spectrum usage demand

The future demand for satellite use will lead to a majority of the designated spectrum being highly used by 2022. As shown in Figure 7.46 and Figure 7.47 below, most bands show high usage (75%–100% of designated band, and in some cases greater than 100% usage). The exception is the 5100–5250 MHz and 5800–5900 MHz bands which show moderate to high (50%–100%) usage in both the minimum and maximum growth scenarios. Frequencies where demand may exceed designation are within the 1500–1700 MHz band, as well as around 1200 MHz (under the maximum growth scenario only).

Figure 7.46: Satellite: average current spectrum usage in the EU-27, minimum growth scenario [Source: Analysys Mason, 2013]

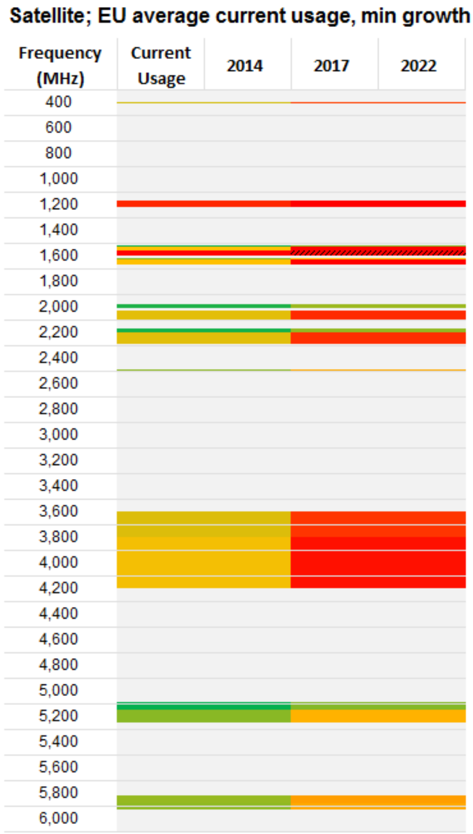
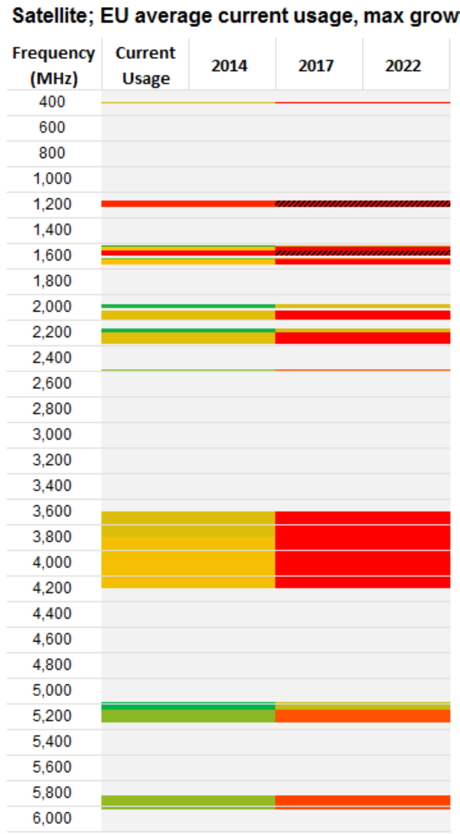


Figure 7.47: Satellite: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]



Differences per country

Future spectrum usage across the eight focus countries shows a degree of homogeneity, as can be seen from Figure 7.48 below. Most countries exhibit high use of most of the spectrum, and in the Czech Republic and Germany usage of the 3800–4200 MHz band is greater than designation. Two countries show moderate usage: Poland in 3800–4200 MHz, and Spain in 3600–3800 MHz.

Figure 7.48: Satellite: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

For the majority of frequencies and scenarios the usage of spectrum for satellite increases, but should remain within current designations. The notable exceptions to this are around 1500–1700 MHz and around 1200 MHz for both the maximum and minimum growth scenarios, based on EU-27 average current usage; and also in 3800–4200 MHz for the EU-27 maximum and for the Czech Republic and Germany.

The high-powered signals that satellites use, and their global footprint, means that satellite services are subject to extensive international harmonisation, which limits the frequency bands in which they operate. Frequency bands and associated orbital arrangements are provided via the ITU-R. Once launched, it is extremely difficult to modify a satellite system, and hence the systems typically remain in place for many years.

7.13 Short-range devices (SRDs)

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

SRDs usually operate in licence-exempt spectrum, which includes the 433 MHz range, 863–870 MHz, 1785–1800 MHz, 1880–1900MHz, 2400–2484 MHz and 5725–5875 MHz (which is used by WLAN applications). This pattern of spectrum usage is in line with the EC Decision 2006/771/EC and its amendments.[166]

Current usage

Current spectrum usage by SRD, as depicted in Figure 7.49, seems to be very homogenous in the focus countries, and indeed across most of the EU-27. The 433–435 MHz, 863–870 MHz and 1880–1900 MHz bands exhibit high usage in all countries. There seems to be some unused spectrum in the 1785–1800 MHz band, and no usage in the 2400–2484 MHz and 5725–5875 MHz bands.

166 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:166:0033:0041:EN:PDF

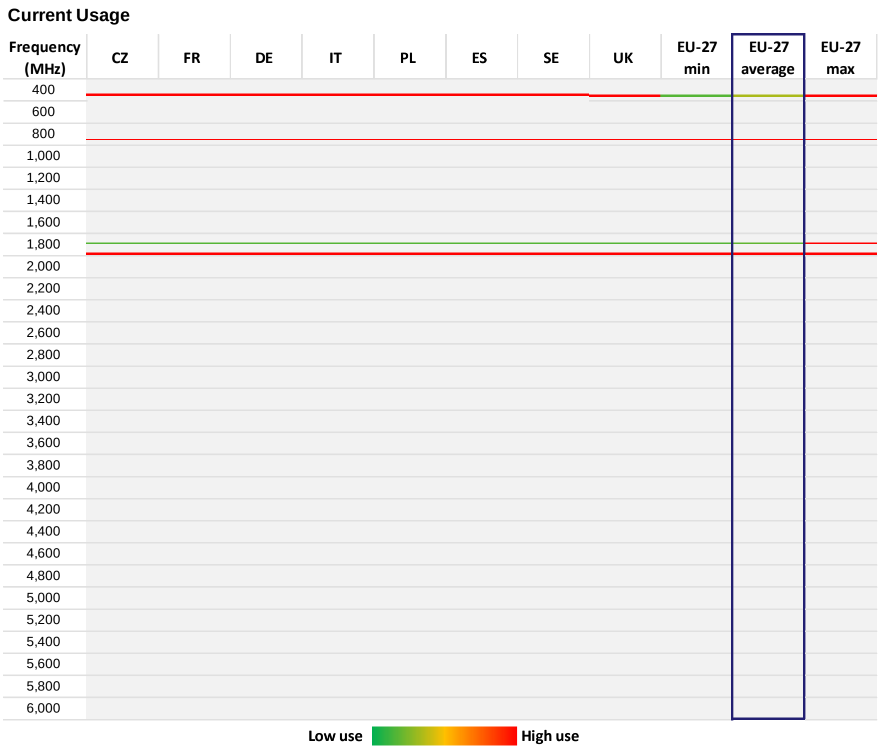


Figure 7.49: Current average usage by SRDs for eight countries and EU-27 min, max and average[Source: Analysys Mason, 2013; WIK Study report, 2012]

Key usage drivers

As mentioned in Sections 5 and 6, there are a broad range of factors that will lead to significant growth in SRD usage in the short, medium and long term. One of the main drivers will be the growth of RFID devices over the next 10 years, due to the commercial benefits that they have and the improvement in their performance and functionality.

The SRD industry has expanded considerably over recent years and has now penetrated into a number of industrial sectors. Uses include automotive applications, alarms, and in wider terms, non-specific SRDs such as home and building automation. It is anticipated that the present trend in diversification and expansion will continue, driving demand for spectrum usage in the next 10 years.

Future spectrum usage demand

For these reasons, spectrum usage demand by SRDs services will experience significant growth. This will require careful attention and planning, as demand is likely to significantly exceed current designation under all scenarios in 863–870 MHz and 1880–1900 MHz, as shown and described below:

- **Short term (2014) and medium term (2017)**: Usage is likely to exceed supply in most bands. The 433–435 MHz band presents a high usage, and the1785–1800MHz band seems to be not fully utilised and might help in managing overall demand.
- **Long term (2022)**: Although gains in spectrum efficiencies will offset demand to a degree, spectrum requirements are still expected to exceed current designations except in the 1785–1800 MHz band. This band might help somehow managing overall growth, but it is unlikely to be sufficient.

Figure 7.50: SRDs: average current spectrum usage in the EU-27, minimum growth scenario [Source: Analysys Mason, 2013]

Figure 7.51: SRDs: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]

Differences per country

Spectrum usage demand in 2022 in the eight studied countries is quite similar, and does not present any differences worth mentioning, as shown in Figure 7.52 on the following page.

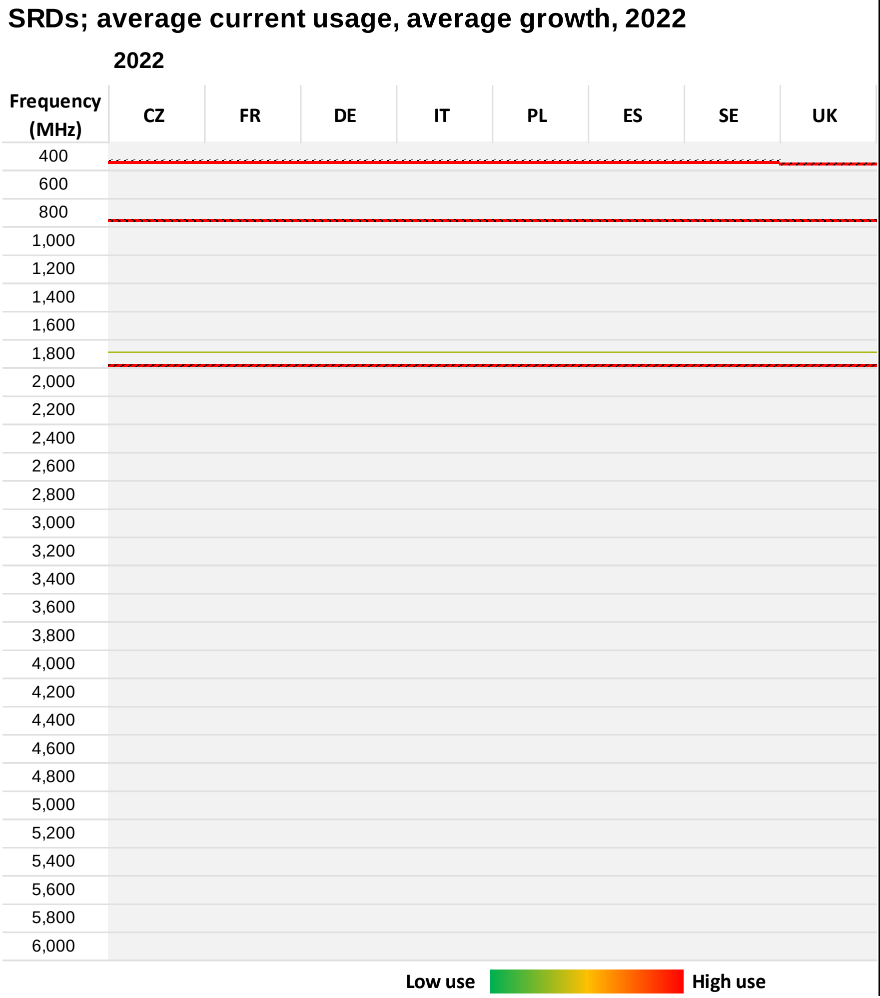


Figure 7.52: SRDs: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

Key SRD bands are in the 433 MHz range and 863–870 MHz. In these bands the future spectrum usage is quite high. Studies are on-going in Europe into possible extended SRD bands above 870 MHz, including the adjacent 870–876 MHz and 915–921 MHz bands. An important requirement from the SRD industry is that any new bands should be an extension of the present SRD bands or close to them.

There are several advantages to future SRD services operating in the 915–921 MHz band. The benefit of harmonisation with the USA means that, for example, tags will be read at the frequency where they are designed to give their maximum response. The increase in power and bandwidth as compared with present 863–870 MHz would increase the reading performance and potentially permit data rates that are four times faster than those currently possible.

In addition, ETSI has identified a need for further spectrum for RFIDs and non-specific SRDs. The main frequency range for RFIDs is currently 903–929 MHz, and in future 915–921MHz has been identified as a band for RFIDs and other high-power devices. 870–876MHz has been identified for non-specific SRDs.

7.14 WLAN/RLAN (WLAN).

Due to significant questions throughout the study, and for the avoidance of doubt, the reader should interpret our conclusions below as focused on current and future spectrum usage and not spectrum designations. However, current and future spectrum usage is estimated in relative terms as a proportion of designated bands and so the results could indicate potential short comings of designated bands. If so, we have indicated this.

However, as explained throughout the report, we have found significant inaccuracy in current spectrum usage levels that, together with the uncertainty on future growth assumptions, means that our conclusions should be interpreted carefully. Nevertheless, we believe our conclusions provide a good guidance to understand potential spectrum demand issues related to future spectrum usage and to inform associated decisions. In particular, it is important to understand the key factors and underlying current and future assumptions that will lead to each scenario in each country, in order to avoid rushing into action without proper consideration. In our view, accuracy in current spectrum usage estimates is more than desirable in this context.

Overview

Currently, the relevant frequency bands of interest to WLAN are just above 80 MHz, in the 2.4 GHz band, and two blocks in the 5GHz band (5150–5350 MHz and 5470–5875 MHz). The 5 GHz band is shared with other application categories. WLAN uses spectrum on a licence-exempt basis.

Wi-Fi devices most commonly operate in the 2.4GHz licence-exempt band designated for industrial, scientific and medical use, though some Wi-Fi devices are also capable of operating in licence-exempt spectrum at 5GHz.

Current spectrum usage

The current spectrum usage by the WLAN category, as depicted in Figure 7.53, is very homogenous in the 2400–2484 MHz and 5 GHz bands across the focus countries and in most of the EU-27. In the eight countries, the level of usage of within these two separate bands is different; the 2400–2484 MHz band presents a high usage (75%–100% of designated band) in all countries, and the 5 GHz band has a low to moderate usage (0%–55% of designated band) except for some specific blocks in the UK, Germany and Spain which have a high usage.

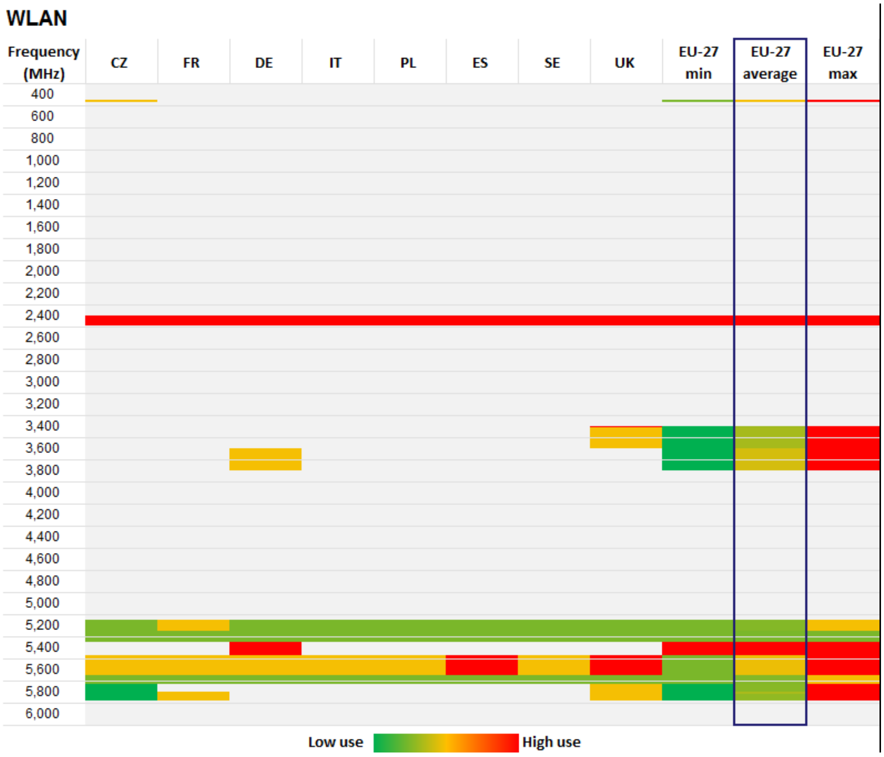


Figure 7.53: Current average usage by WLAN for eight countries and EU-27 min, max and average[Source: Analysys Mason, 2013; WIK Inventory Study, 2012]

For consistency with the other categories, our assessment of current spectrum use by WLAN is based on the WIK Study. However, comparing the eight focus countries, we believe there are some inaccuracies in the study. For example the 3.6 GHz band in Germany is not used for WLAN.

Key drivers for future spectrum usage

As mentioned in Section 5 and Section 6, there are a broad range of factors that will give rise to significant growth in WLAN usage in the medium and long term. The driver that will have the greatest higher impact in the next 10 years is the continued expansion in the reach of Wi-Fi networks and the increasing adoption by users, especially for broadband and HD video applications. In particular, similar to mobile, spectrum usage will be driven by strong take-up of more sophisticated mobile and portable devices (e.g. smartphones, tablets and laptops) which increase traffic due to higher data consumption, and especially video usage. Increasingly, Wi-Fi carries most of the traffic generated by these devices, whether they are used at home, in the office or during nomadic usage.

Another driver is the demand from operators offloading mobile network traffic onto fixed networks in order to get a higher quality of service when the spectrum for mobile is above the limit of its capacity. This Wi-Fi offloading will increase the amount of traffic carried over Wi-Fi networks and decrease the demand for mobile spectrum.

Future spectrum usage demand

Spectrum usage demand by WLAN services will experience significant growth, requiring careful attention and planning as demand is likely to significantly exceed current designations in some bands.

- **Short term (2014)**: In the minimum growth scenario, although some bands present a high average usage, usage does not seem to exceed spectrum designation. However, in the maximum growth scenario usage is likely to exceed supply, mainly in the 2.4 GHz and 5.4 GHz bands. Some frequencies appear to remain not fully utilised, though, specifically the 5.2 GHz and 5.8 GHz bands; these might help managing overall demand.

- **Medium term (2017)**: Under both the minimum and maximum growth scenarios, usage is likely to exceed supply in the same frequencies as in the short term (2.4GHz and 5.4 GHz bands). However MHz, 5.2 GHz and 5.8 GHz bands are still not fully utilised in the minimum growth scenario. Under the maximum growth scenario all bands present a high usage.

- **Long term (2022)**: Although gains in spectrum efficiency will offset demand to some degree, future spectrum requirements in the 2.4 GHz and 5.8 GHz bands will exceed current designations under both growth scenarios, suggesting additional spectrum might be required in similar bands.

Overall, as the 5 GHz band is shared this may have an impact on the other usage categories.

Figure 7.54: WLAN: average current spectrum usage in the EU-27, minimum growth scenario [Source: Analysys Mason, 2013]

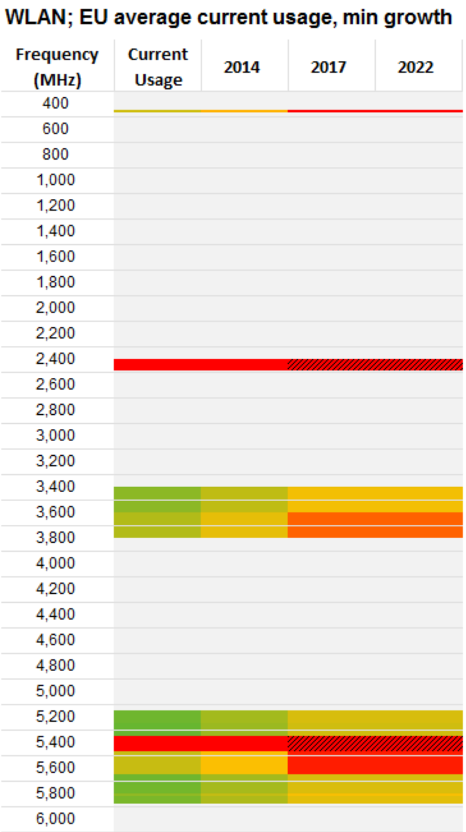


Figure 7.55: WLAN: average current spectrum usage in the EU-27, maximum growth scenario [Source: Analysys Mason, 2013]

Differences per country

Spectrum usage demand in 2022 in the eight studied countries is quite similar. The main conclusions are:

- Whilst the 2.4 GHz band is heavily used in all countries (above 100%), other licence-exempt spectrum at 5 GHz is not yet used as extensively.
- In the Czech Republic, 450–470 MHz has been designated to WLAN, and in 2022 this band has a high usage (75%–100% of designated band). The 5GHz band presents unused spectrum.
- In Germany, the 5GHz band presents some unused spectrum, while usage is above 100% in some frequencies (the 5350–5450MHz sub-bands) which are shared with Defence and PMSE.
- In the UK, the 5 GHz band presents some unused spectrum, while usage is above 100% in some frequencies (the 5540–5620 MHz sub-bands) which are shared with Defence, PMSE and PPDR.

Figure 7.56: WLAN: spectrum usage in focus countries in 2022, based on average current usage and average growth scenario [Source: Analysys Mason, 2013]

Conclusions

Based on average current usage and the different growth scenarios, there seems to be a clear indication that average future spectrum usage will exceed 100% of current designations, particularly in the 2.4 GHz and 5470–5720 MHz bands. There is potential to meet part of this demand in the 5 GHz band, which has considerably more capacity, even though these frequencies are likely to be more range-limited. It is probable that take-up of this band, which is shared with some military and civil radar systems, will increase in response to growing congestion at 2.4 GHz and the availability of devices able utilise the 5 GHz band.

There is 320 MHz available in the 5 GHz band that may be released for WLAN services. 120 MHz of spectrum could be released in the 5350–5470 MHz band, and 200 MHz in the 5725-5925 MHz band. Some EU-27 countries are already using the top of the band for WLAN services.

There may also be a demand for access to lower frequencies for WLANs to improve coverage – ideally this would require access to frequencies below 1 GHz.

There are a number of factors which may mitigate the future usage demand described above:

- Less traffic than expected may be offloaded from mobile networks to Wi-Fi due to a consumer preference for mobility services.
- There may be fewer Wi-Fi-enabled devices than assumed.
- Ultra Wide Band technology may complement Wi-Fi for short-range uses, as well as other short-range high-data-rate technologies using licence-exempt spectrum at 60 GHz (the advantage of these bands and technologies is the prospect of ready harmonisation internationally).
- Finally, the limited range of 5GHz frequencies may reduce the quality of service and encourage consumers to use mobile or wired services.

8 Conclusions

This section provides the main conclusions of the work carried out to analyse technology trends, future needs and demand for spectrum, in line with Art.9 of the RSPP. Our conclusions are based on the requested methodology and take account of the feedback received; they are presented under five headings, as follows:

- methodology overview and key initial issues
- impact on spectrum demand of technology trends, and consumer and community trends
- future usage by category and band
- future usage by country
- overall conclusions and potential next steps.

8.1 Overview of methodology and issues with data

8.1.1 Definition of the application categories used

Our analysis assesses levels of spectrum usage demand broken down into the various types of application groupings that use the spectrum. In order to be consistent with the Commission Implementing Decision (2013/195/EU), we have used the same 14 application categories included in the Decision:

1. Aeronautical, maritime and civil radiolocation and navigation systems (AMCRN)
2. Terrestrial broadcasting (Broadcasting)
3. Cellular/BWA (Mobile)
4. Defence systems (Defence)
5. Fixed links (Fixed)
6. Intelligent transport systems (ITS)
7. Meteorology (MET)
8. Private mobile radio/public access mobile radio (PMR/PAMR)
9. Programme making and special events (PMSE)
10. Public protection, disaster relief (PPDR)
11. Radio astronomy (Science)
12. Satellite systems (Satellite)
13. Short-range devices (SRDs)
14. WLAN/RLAN (WLAN).[167]

We have some concerns about these application categories, and how different applications should be categorised and demand estimated. This is based on significant criticism by stakeholders during the workshops about the criteria underlying the definitions, and the potential overlap between categories. It is important to be clear about which applications are included under each category

167 Formerly called wideband data transmission systems.

and the exact mapping with EFIS layers, to minimise duplication or overlaps. However, we note that the changes in applications and categories suggested by stakeholders would not significantly affect the results of our study.

8.1.2 Data on current spectrum usage

Our initial aim was to develop a *quantitative* estimate of the demand for future spectrum usage across the EU-27. In order to do this, we needed to develop a good understanding of current demand for spectrum usage in each Member State, broken down by category and frequency band. We would have then applied different growths based on technology, consumer and community related trends. However, obtaining an accurate quantitative estimate of current spectrum usage proved impossible and we have been forced – with the agreement of the EC – to move to a *qualitative* and *relative* estimate of future demand for spectrum usage.

The primary reason for this change in approach was the quality of the data available to us. The main source of information on current spectrum usage is EFIS, the European Communications Office Frequency Information System. However the data provided by EFIS has a number of limitations, such as:

- the EFIS definition of "application" and "allocation" is not clear
- within the same application category, there are unrealistic differences between countries, for example the data for AMCRN in France compared to other countries
- the data in some categories seems to be wrong, for example the data for Satellite in Germany
- many countries do not have data for several categories, for example Italy for ITS, PMR or Science
- there is a lack of data for many categories, for example Defence.

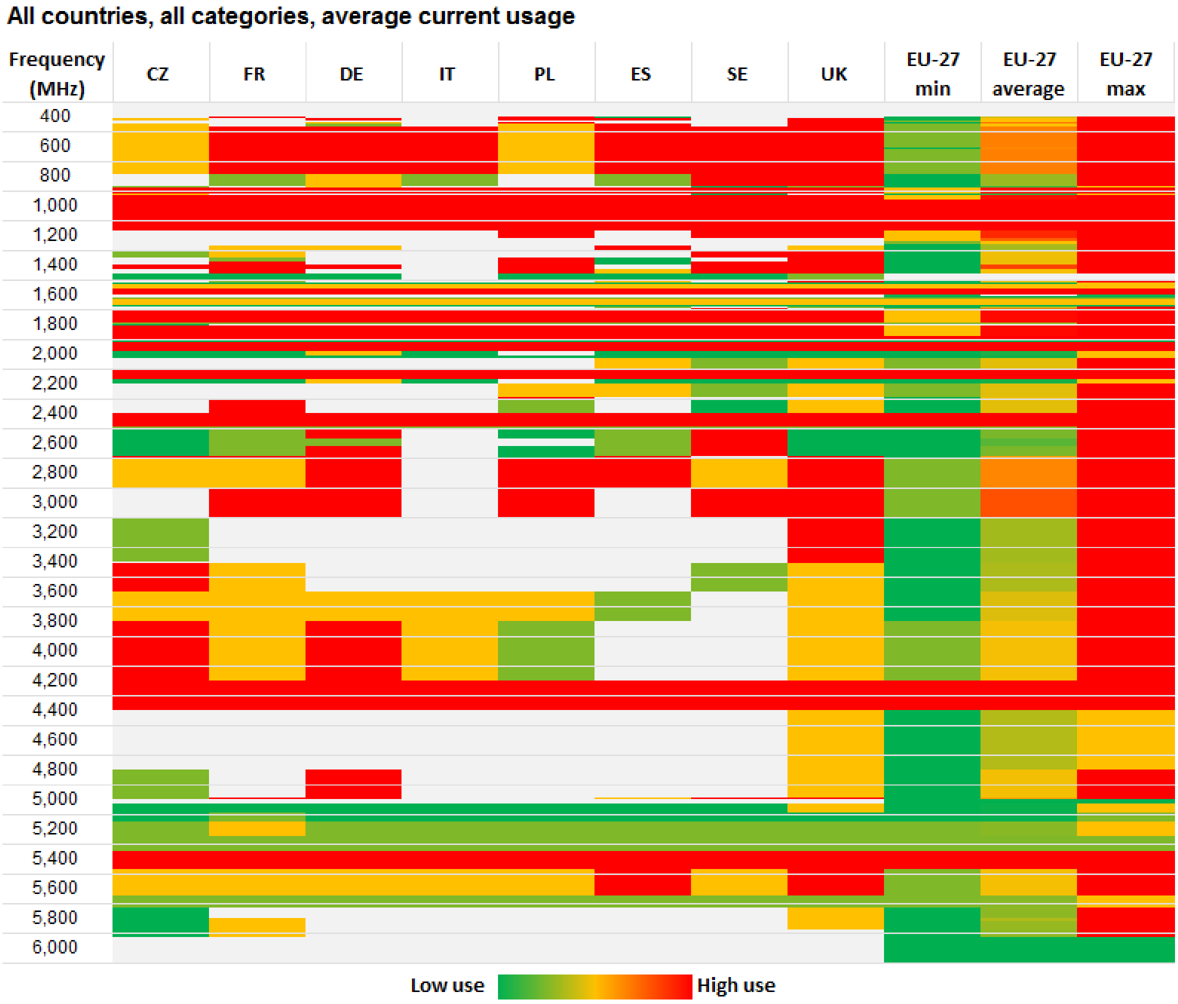
Therefore, we came to the conclusion that the existing data is not reliable enough to form a basis for accurate *quantitative* forecasts of future spectrum usage. Such a quantitative analysis would require a thorough review of the existing data on current spectrum usage, and the provision of additional inputs from the EC, Member States and stakeholders, as specified in the new Commission Implementing Decision (2013/195/EU): "*Data should be provided by Member States in the most consistent way possible, either through the European Communications Office Frequency Information System (EFIS), or directly to the Commission.*"

There are also some uncertainties regarding the designation of some spectrum bands in some countries, which make difficult to estimate future demand. This may be illustrated by the possible designation of spectrum in the 700 MHz band to mobile services (in the 694-790 MHz range) and associated decisions. The UK is planning to award the 600 MHz band for broadcasting alongside PMSE, whereas France has indicated that it might not offer any spectrum to compensate for the potential reduction of Broadcasting allocations in the 700 MHz band.

8.1.3 Current situation – a qualitative approach

As discussed earlier in this report, due to the lack of quantitative data we decided (in agreement with the EC) to take a qualitative approach, taking as a starting point the qualitative estimates provided in the WIK Study. The figure below presents a heatmap showing the current average spectrum usage, by study country and by usage category, across the entire frequency range (in steps of 10 MHz) from 400 MHz to 6 GHz. In addition, at the EU-27 level, the heatmap also shows the minimum, average and maximum current usage.

Figure 8.1: Heatmap showing current average spectrum usage for all applications [Source: Analysys Mason, 2013 and WIK Study]



From this figure we can derive the following points about current spectrum usage:

- Spectrum usage varies between the eight focus countries, and in particular current usage is quite high in some countries like the UK compared to other countries such as the Czech Republic. This diversity in the current situation in different Member States needs to be considered carefully when interpreting the European perspective. This diversity is also reflected in the difference between the minimum and the maximum usage in Europe as a whole.

- Some frequencies, such as the 2 GHz, 3.6 GHz and 3.8 GHz bands, appear to have a low usage in most of the focus countries, while other bands such as 1000 MHz and 5.4 GHz appear to have a high usage.
- There is lack of information relating to some frequencies, such as the 4.6 GHz, 4.8 GHz and 6 GHz bands, and also a limited amount of data for some countries like Italy, Spain or Sweden.

8.2 Impact on spectrum demand of technology, consumer and community trends

There are a large number of technology trends and consumer and community trends that are having, and will have, an impact on the demand for future spectrum usage. On the one hand, the development of new spectrally efficient technologies will lead to an increase in spectrum capacity, though in some cases the migration to these new technologies will be made very gradually. Some technologies will be simulcast with the legacy technologies, so that for a certain period the demand for spectrum will actually be higher; and in some cases new technologies will even stimulate demand.

It is unlikely, however, that the development of technologies that are more spectrum-efficient will be enough to satisfy the growing demand arising from most of the consumer and community trends in the majority of the application categories. This situation is summarised in Figure 8.2 overleaf, which presents a complete list of the technology, consumer and community trends, and their overall impact on demand for future spectrum each for each category. We have used the following scale to rate the expected impact:

++	More than a 50% increase
+	Up to a 50% increase
=	Limited impact
–	Up to a 50% reduction
– –	More than a 50% reduction

The impact assessment is made for three periods: short term (2012–2014); medium term (2012–2017); and long term (2012–2022). As can be seen, in all categories except Fixed Links, Science and Meteorology, there is expected to be an increase of demand for future spectrum usage in the long term. We have also taken into account of specific demand for new spectrum where there is no usage today and a growth factor is therefore not applicable. It should be noted that future spectrum usage growth does not necessarily mean that there will be demand for spectrum in excess of spectrum designations: we explore the balance of future spectrum usage and designations in the following sub-section.

Figure 8.2: Overall assessment of the impact of technology, consumer and community trends on spectrum usage demand, by category [Source: Analysys Mason, 2013] Note: EU bands = Common bands across the EU-27.

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
AMCRN *960–1350 2700–3100 4200–4400 5030–5150*	***Key factors driving spectrum usage demand for AMCRN****: high-speed broadband and live-TV services in-flight; the integration of RPAS into the civilian airspace; and advances in radiolocation services*		**=**	**=/+**	**+**
	Advances in radiolocation services	Technology	–/=	–/=	–/=
	Wireless avionics intra-communications	Technology	=	=	=
	Digital enhancements of analogue maritime mobile systems	Technology	=	=	=
	Direct air-to-ground communication	Technology	+	+	+
	Remotely piloted aircraft systems	Technology	+	+	+
	Digital enhancement of communications systems	Technology	=	=	=
	Growth in air passenger traffic	Consumer	=	=/+	=/+
	Growth in air freight traffic	Consumer	=	=/+	=/+
	Growth in sea freight traffic	Consumer	=	=	=/+
	High-speed broadband and live-TV services in-flight	Consumer	=	+	++
	Implementation of Single European Sky ATM Research (SESAR), 'the spectrum / technology' dimension of SES	Consumer	=	=/+	=/+
	Mandates to implement technology advances	Consumer	=	=/+	=/+
	Integration of RPAS into the civilian airspace	Consumer	=/+	+	++
Broadcasting *470–790*	***Key factors driving spectrum usage demand for broadcasting***: implementation and adoption of HDTV, UHDTV and 3DTV; and the technology migration path		**+**	**+/++**	**+/++**
	Development of alternative platforms to DTT	Technology	–/=	–	–
	New digital video formats	Technology	++	++	++
	Broadcasting encoding and transmission developments	Technology	=/+	=	– –
	Analogue switch-off / digital switchover	Technology	–/+	–	–
	Single-frequency network (SFN)	Technology	–/=	–	–
	Mobile TV / DVB-H	Technology	–	–	–
	Growing linear TV consumption	Consumer	=	=	=
	Growth in the number of TV channels	Consumer	+	=	=
	Adoption of DTT	Consumer	=	=	=
	Implementation and adoption of HDTV/UHDTV/3DTV	Consumer	+	++	++
	Take-up of DAB	Consumer	=	=/+	=/+
	Adoption of OTT and impact on DTT	Consumer	=	=	=

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
	Number of MUXs	Consumer	+	+	+
	Digital television switchover in CEE	Consumer	=/+	=	=
	Technology migration path	Consumer	+	++	++
Mobile *790–862* *880–915* *925–960* *1710–1785* *1805–1880* *1900–1980* *2010–2025* *2110–2170* *2500–2690* *3400–3600*	***Key factors driving spectrum usage demand for mobile***: development and adoption of more sophisticated devices; the extent of traffic being offloaded onto Wi-Fi networks (by both consumers and operators); and the launch of 3.5G/4G (LTE/LTE-Advanced) technologies		**+**	**+/++**	**+/++**
	Launch of LTE/LTE-Advanced	Technology	=/+	=	– –
	Growth in Wi-Fi offload	Technology	–/– –	–/– –	–/– –
	Development and adoption of more sophisticated devices	Technology	+	++	++
	Spectrum sharing and white spaces	Technology	–	–	–
	Femtocells	Technology	–	–	–
	In-building wireless	Technology	–/=	–/=	–/=
	WiMAX developments	Technology	–/=	–/=	–/=
	Launch of LTE/LTE-Advanced	Consumer	+	+	+
	Growth in Wi-Fi offload	Consumer	–	– –	– –
	Development and adoption of more sophisticated devices	Consumer	+	++	++
	Adoption of data-hungry mobile applications	Consumer	++	++	++
	Increase of mobile data speeds	Consumer	++	++	++
	Adoption of M2M	Consumer	=	=	=
	Deployment of femtocells	Consumer	=/–	=/–	=/–
	Number of mobile network operators	Consumer	=	=/–	=/–
	Spectrum sharing and white spaces	Consumer	=	–	–
Defence *406–410* *430–433* *435–446* *446–450* *870–876* *915–921* *1300–1350* *1518–1525* *2025–2110* *2200–2400* *3100–3410* *4400–5000* *5150–5350*	***Key factors driving spectrum usage demand for defence*****:** growth in the number of connected devices and in the amount of information exchanged; development and take-up of unmanned aeronautical systems; and limited changes in positioning and navigation technologies		**=**	**+**	**++**
	Growth in information exchange (enhanced connectivity)	Technology	++	++	++
	Potential compression benefits from new technologies (i.e. detection and radar improvements)	Technology	=	=	=
	Positioning and navigation	Technology	=	=	=
	Information acquisition	Technology	+	+	+
	Growth in activity in the Defence sector	Consumer	=	+	+
	Growth in information exchanged (enhanced connectivity)	Consumer	=	+	++

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
	Increase in unmanned aeronautical systems	Consumer	=	+	++
	Potential compression benefits from new technologies	Consumer	=	= / +	+
	Potential of freeing spectrum allocated to Defence	Consumer	=	=	=
	Increase in satellite use with civil and governmental assets	Consumer	+	+	++
	Potential to switch to commercial services/operators	Consumer	=	=/+	=/+
Fixed links *1350–1400* *1427–1452* *1492–1525* *1700–1710* *2025–2110* *2200–2290* *3800–4200* *5925–6425*	***Key factors driving spectrum usage demand for fixed links***: the degree of substitution by fibre networks; and the migration of fixed links to higher frequencies		**=/–**	**–**	**– –**
	Microwave to fibre substitution	Technology	– –	– –	– –
	Higher-frequency links	Technology	– –	– –	– –
	NLoS/QLoS backhaul	Technology	+	+	+
	Improved modulation techniques	Technology	–	–	–
	Use of XPIC	Technology	–	–	–
	Other technology advances	Technology	=	=	=
	Zero-footprint advances	Technology	=	=	=
	Microwave to fibre substitution	Consumer	= / -	= / -	- / --
	Demand for higher-frequency links	Consumer	- / --	- / --	- / --
	Deployment of new mobile stations	Consumer	+	+/++	+/++
	Take-up of services that require low latency	Consumer	=	=	=
ITS *5795–5815* *5875–5905*	***Key factors driving spectrum usage demand for ITS***: the development and take-up of new ITS applications		**=**	**+**	**++**
	New ITS applications	Technology	=	+	+
	Vehicle-to-vehicle communications	Technology	+	+	+
	Rail applications	Technology	=	=	=
	New ITS applications	Consumer			
	Traffic and freight management	Consumer	=/+	+	+
	Integration vehicle-infrastructure	Consumer	=	+	++
MET *401–406* *1675–1710* *5350–5650*	***Key factors driving spectrum usage demand for MET***: maintain current spectrum designations for meteorology due to their specific physical properties		**=**	**=**	**=**
	Radar improvements	Technology	=	=	=
	Satellite services	Technology	=	=	=
	Global Observing Systems (GOS)	Consumer	=	=	=
	WIGOS	Consumer	=	=	=
	Harmonisation	Consumer	=	=	=

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
PMR/PAMR *406–433* *435–470* *870–880* *915–925*	***Key factors driving spectrum usage demand for PMR***: the introduction and take-up of smart grid and smart metering applications		**=/+**	**+**	**+**
	Digital replacements	Technology	–/=	–/=	–/=
	Smart grid and smart metering	Technology	++	++	++
	Smart grid and smart metering	Consumer	=/+	+	+
	General PMR/PAMR	Consumer	=	=	=/+
	ECTS and GSM-R replacement	Consumer	=	=	=
PMSE *470–790* *1785–1800* *2025–2110* *2200–2400* *3100–3400*	***Key factors driving spectrum usage demand for PMSE***: the type and number of events; the type of equipment; the increase in the amount of equipment per event; and the adoption of HD and 3D cameras		**+**	**+**	**+**
	Adoption of HD and 3D cameras	Technology	++	++	++
	Digital microphones	Technology	=	=	=
	Mobile broadcast systems	Technology	+	+	+
	Higher-frequency wireless cameras	Technology	=	=	=
	Adoption of HD and 3D cameras	Consumer	+	+	++
	Type and number of events	Consumer	+	+	+
	Type of equipment and growth	Consumer	+	+	+
	Increase in the number of equipment per event	Consumer	+	+	++
PPDR *3100–3400* *4940–4990*	***Key factors driving spectrum usage demand for PPDR***: increasing demand for data-rich applications; and the potential for PPDR services to make use of commercial services and networks		**=**	**+**	**++**
	TETRA 2 (TEDS)	Technology	=/+	+	+
	PPDR high-speed data networks	Technology	=/+	+	++
	Use of commercial networks	Technology	–/=	–/=	–/=
	Demand for data-rich applications	Consumer	=	+	++
	Growth in security requirements	Consumer	=	+	+
	Potential to switch to commercial services	Consumer	=	=	=
	Level of adoption of new technologies	Consumer	=	=	=
Science *1400–1427* *1610–1614* *1661–1675* *2290–2300* *2690–2700* *4940–5000*	***Key factors driving spectrum usage demand for Science***: maintain current spectrum designations for meteorology due to their specific physical properties		**=**	**=**	**=**
	More powerful back-end processing	Technology	=	=	=
	Very long baseline interferometry	Technology	=	=	=
	Allocation demand	Consumer	+	+	+
	Usage demand	Consumer	=	=	=

Category EU bands (MHz)	Main trend	Trend type	Demand for future spectrum usage		
			ST	MT	LT
Satellite *1164–1215 1525–1610 1614–1661 1980–2110 2170–2290 2484–2500 3600–4200 5000–5030 5875–6425*	***Key factors driving spectrum usage demand for Satellite:*** the increase in backhaul services within the C-band as well as the surge in demand for the S-band		**=/+**	**+**	**+**
	Galileo navigation system	Technology	=/+	=/+	+
	High-speed satellite broadband	Technology	=	=	=
	Mobile satellite services	Technology	=	=	=
	L-band MSS	Technology	+	+	+
	Ku-band FSS	Technology	=	=	=
	Satellite L-band DAB	Technology	–	–	–
	M-LNB	Technology	=	=	=
	L-Band	Consumer	=	=	=
	S-band	Consumer	=	+	+
	C-band	Consumer	=/+	=/+	=/+
	Amateur satellite	Consumer	+	+	+
SRDs *433–435 863–870 1785–1800 1880–1900*	***Key factors driving spectrum usage demand for SRDs***: the growth of RFID devices and growth in different applications		**+**	**+**	**+**
	Technology developments	Technology	–	–	–
	Harmonisation of modulation techniques	Technology	=	=	=
	Growth in the use of SRDs for medical apps	Technology	=/+	=/+	=/+
	Growth of RFID devices	Technology	+	+	+
	Geo-location databases	Technology	–	–	–
	Growth of alarms	Consumer	+	+	+
	Growth of home and building automation	Consumer	+	+	+
	New requirements in the automotive industry	Consumer	+	+	+
	Geo-location databases	Consumer	–	–	–
	Take-up of automotive SRDs	Consumer	+	+	+
	Growth in the use of SRDs for medical apps	Consumer	+	+	+
	Harmonisation of modulation techniques	Consumer	=	–	–
WLAN *2400–2484 3400–3410 5150–5350 5470–5875*	***Key factors driving spectrum usage demand for WLAN***: the continued growth in Wi-Fi network reach and user adoption		**+**	**+**	**+**
	Growth in the number of hotspots	Technology	+	+	+
	New Wi-Fi standards	Technology	+	+	+
	Wi-Fi roaming (offloading)	Technology	+	+	+
	Growth in the number of hotspots	Consumer	+	+	+
	Continued growth in Wi-Fi network reach and user adoption	Consumer	++	++	++
	Rural fixed wireless access	Consumer	=	-	-
	Release of spectrum designated to WiMAX	Consumer	=	=	=/-

8.3 Future spectrum usage by category and band

In Figure 8.3 overleaf we provide a heatmap showing the usage in 2022 of each spectrum band by each of the application categories, and also provides an overall EU-27 average. The scenario shown is based on average current spectrum usage, with average growth to 2022. As mentioned in the previous sections, there are regions of the spectrum that are likely to experience more than 100% usage of the current designation by 2022 – these cases are indicated with diagonal shading. Some application categories, such as AMCRN, exhibit high usage across a larger number of bands than others.

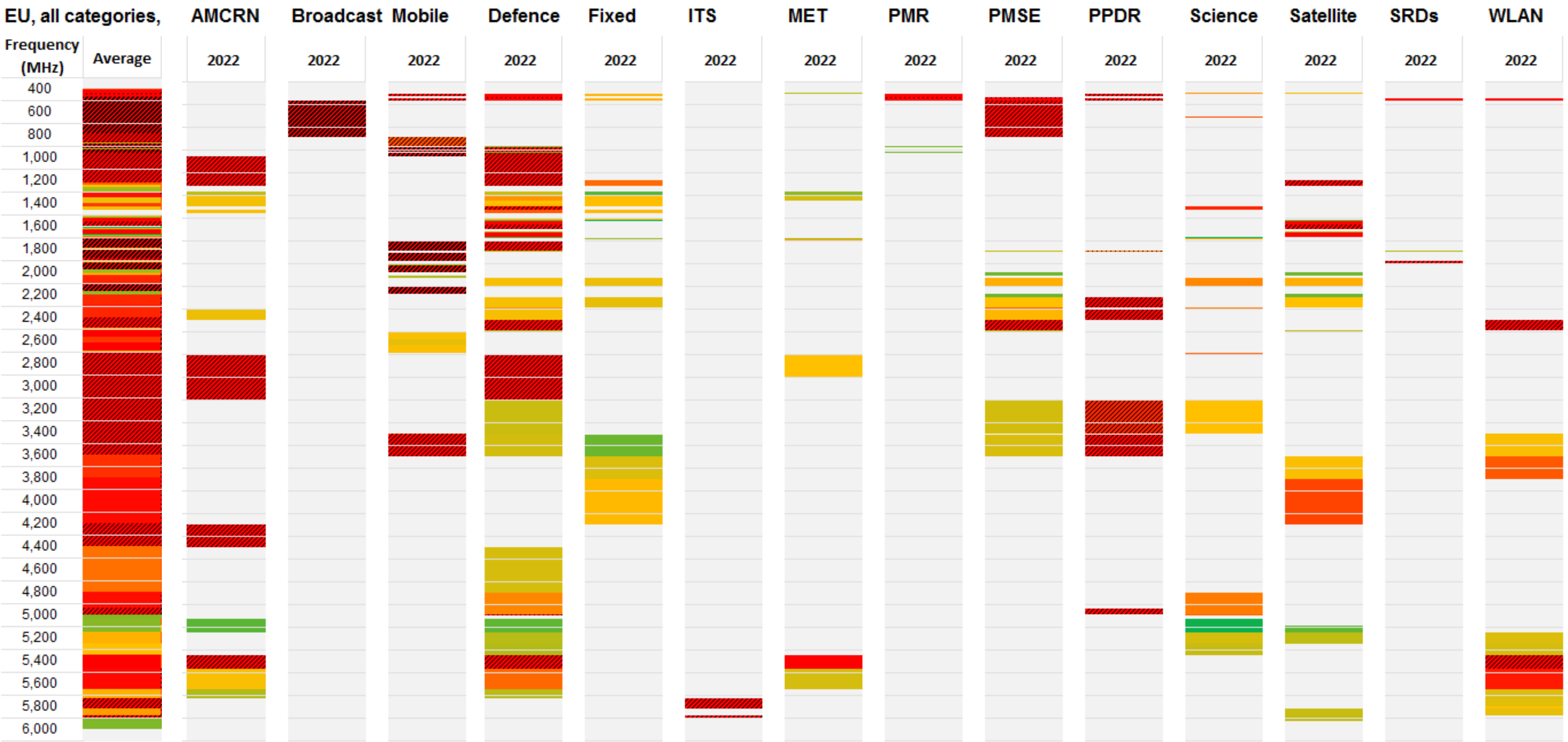
The main frequencies bands where future spectrum demand usage is above 100% of the current designation are:

- 400–1200 MHz, due to broadcasting, mobile and possibly defence
- 1700–2200 MHz due to mobile and possibly defence
- 2700–3100 MHz due to AMCRN, PPDR and possibly defence
- 4200–4400 MHz due to AMCRN
- 4900–5000 MHz due to PPDR
- 5750–5850 MHz due to ITS.

There are, conversely, areas of the spectrum that show less than 100% usage of designation by 2022 in this scenario, notably:

- 1200–1400 MHz where AMCRN, defence, fixed and MET may benefit
- 2000–2100 MHz, where a number of categories may benefit
- 3600–4100 MHz, where fixed and satellite may benefit
- 4400–4900 MHz, where defence is the only application present
- 5000–5400 MHz, where a number of categories could benefit
- 5650–5750 MHz, where a number of categories could benefit
- 5850–6000 MHz, where ITS and satellite may benefit.

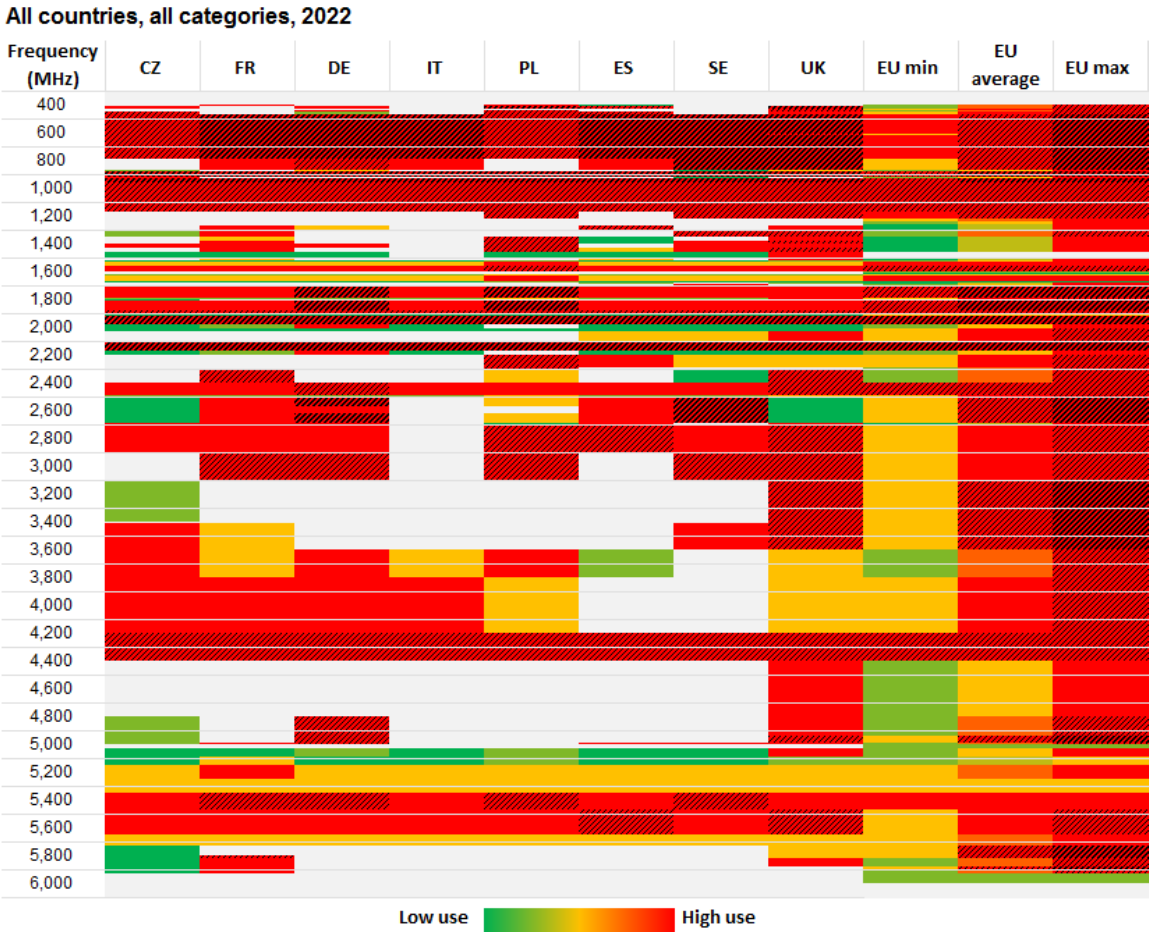
Figure 8.3: Heatmap showing spectrum usage in 2022, by application category, based on average current usage and the average growth scenario [Source: Analysys Mason, 2013]



8.4 Future usage by country

The picture of spectrum usage is very different in each country, and to provide some insight into this we have made estimates of future usage demand for the eight focus countries. to illustrate different potential outcomes and situations that will need to be considered. Figure 8.4 shows a heatmap of spectrum used by all categories across the eight countries in 2022, based on average current usage and the average growth scenario. The figure also shows the EU-27 minimum, average and maximum usage.

Figure 8.4: Heatmap showing spectrum usage in 2022 in the focus countries, and the EU-27 minimum, average and maximum usage [Source: Analysys Mason, 2013]



As can be seen, in some regions of the spectrum there are significant differences in future demand across the focus countries, while in other regions the picture is more homogeneous:

- **Sub-2 GHz bands**: usage is fairly homogeneous across the eight countries.
- **2–3 GHz region**: there is a more mixed range of usage across the eight countries, particularly in 2500–2700 MHz, where for example the Czech Republic and the UK show low usage whereas Sweden and the EU average show a usage above 100% of current designation.

- **3–5 GHz region**: the picture here is also fairly heterogeneous; for example, usage in 3600–3800 MHz ranges from low in the EU minimum case and Spain, to over 100% in the EU maximum case.
- **5–6 GHz: region**: usage is fairly homogenous across the eight countries.

8.5 Overall conclusions and potential next steps

Overall, even though we have not been able to estimate quantitatively the demand for future spectrum usage, we believe that our results provide a solid base to inform future spectrum usage and needs, and to highlight areas that require further work to improve the accuracy of the results. In particular, we believe that the results of this study are very useful to inform the debate about the direction, scale and timing of future spectrum usage demand, together with the key drivers that will determine this demand. However, there are some issues that need further work, and some actions to be taken.

- There are significant differences in spectrum usage across the focus countries, both currently and in the future. This is also shown by the differences between the minimum and maximum usage in the EU-27 as a whole. The main differences are between 2 GHz and 5 GHz frequency ranges.
- For most application categories there is significant uncertainty regarding the impact on spectrum demand of the different technology, consumer and community trends, particularly in the longer term. Many research houses that provide forecasts for the different trends do not provide data for the long term. Moreover, estimates vary widely between the various research houses, and their forecasts are adjusted annually.
- There are also some uncertainties regarding the designation of some spectrum bands in some countries, which make it difficult to accurately estimate the demand for future spectrum usage. One example is the possible designation of spectrum in the 700 MHz band (in the 694–790 MHz range) to mobile services.
- Future spectrum usage – across most frequencies – will increase significantly over the next 10 years. However specific nature of the congestion problem is completely different in the short term, medium term and long term. Generally, congestion problems begin to appear mainly in the medium term.
- Since for most categories demand for spectrum is increasing, more sophisticated sharing of spectrum is increasingly important – for example based on white spaces. It is therefore important to invest more time and resources in identifying and developing possibilities for spectrum-sharing.
- It is important to note that many bands are not exclusively used by one type of application, but are often shared with other categories. In theory, therefore, clearing this spectrum for other users would require the sharing services to vacate the spectrum as well. For this reason, many of the results of any calculations will tend to be lower than may be necessary in reality.

- For some categories, spectrum may also not be used on a regular basis, or only in limited geographical areas – for example, some of the spectrum allocated for defence use. This may raise the possibility for some of this spectrum to be made available for use by other categories under carefully designed conditions.
- Some categories are interrelated, and therefore in some cases demand by one category will reduce demand by another. For example, the spectrum demand for both mobile and Wi-Fi is driven mainly by the growth in on-demand video and audio-visual services on tablets, smartphones and other devices. In such cases, satisfying demand from one category is likely to be at the detriment of the other category – and different stakeholders will have different perspectives on how such competing demands should be met.
- Some actions that are currently being discussed to reduce future congestion problems have not been included in our qualitative estimations – for example, there are some studies ongoing in Europe into extending SRD bands above 870 MHz.
- Existing data on current spectrum usage is not reliable enough to form a basis for accurate quantitative forecasts of spectrum usage demand. To remedy this, it is important that Member States improve their knowledge of current spectrum usage and make this data publicly available.
- There are concerns about the 14 application categories and how these should be categorised and demand estimated. It is important to be clear about which applications are included under each category, and the exact mapping onto EFIS layers, in order to minimise duplication or overlaps.
- We would like to note that the scope of this study does not include any assessment of the societal and economic benefits of spectrum and the various applications that use it.

Annex A Other existing studies consulted for this report

Over the past two years, spectrum demand has been the focus of a large number of studies, reports and lobbying pieces, from all areas of the telecoms, media and broadcasting industry and other user communities (e.g. security, emergency and defence), in addition to the sometimes extensive analyses and consultations published by regulators and spectrum management agencies.

During this project we have consulted a large number of reports. The bibliography is shown in the tables below.

Figure A.1: List of studies pertinent to Member States of the EU [Source: Analysys Mason, 2012]

Country	Study	Author	Outline
Global	*Spectrum for future development of IMT-2000 and IMT-Advanced* (2012)	UMTS Forum	This paper argues that identification of additional IMT spectrum should be an agenda item for WRC-15 and that additional studies should be conducted on future IMT spectrum requirements. In addition, the study calls for harmonised utilisation of spectrum for IMT systems
EU-wide	*The European market for the use of UHF white space* (2011)	J. Stewart and M. Mullooly, Analysys Mason	This report focuses on UHF spectrum and potential services and technologies that could use white spaces. The report lists standards being developed to use UHF white space and regulatory developments relevant to controlling access to UHF white space
EU-wide	*Inventory and review of spectrum use: Assessment of the EU potential for improving spectrum efficiency"*	WIK-Consult for the EC	This study outlines the process of creating a spectrum inventory for the EU as well as the current usage of designated bands within the EU
UK	*Spectrum demand for non-government services 2005–2025* (2005)	Analysys Mason	This report forecasts the future demand for radio spectrum in the UK for commercial service (i.e. non-government) use within the frequency range 0–15GHz. It covers major applications
	Defence Demand for Spectrum: 2008–2027 (2008) (Ministry of Defence, Final Report)	PA Consulting	This report reviews current usage in a large number of bands, as well as future plans which could affect the level of demand
	Predicting Areas of Spectrum Shortage (2009) (Ofcom, Final Report)	PA Consulting	This report uses a scenario-based approach to look at demand for major commercial applications to 2025

Country	Study	Author	Outline
	Assessment of market demand for spectrum allocated to the public sector (2011)	Plum Consulting	This report is fairly high level, but considers demand drivers for major applications
	Enabling UK growth – Releasing public spectrum (2011)	DCMS	Inter alia, this report considers potential commercial demand for additional spectrum (partly based on Plum's work)
	Report for Ofcom: 4G capacity gains (2011)	Real Wireless	This report provides an assessment of the "*realistic scope for capacity improvements in 4G technologies compared to 3G technologies*"
	Frequency Band Review for Fixed Wireless Service (2011)	AEGIS, Ovum and dB Spectrum Services	This report covers current usage of fixed link bands (for fixed links and other services), factors affecting future demand, and scenario-based forecasts of future demand. Subsequent consultation by Ofcom (conclusions not yet published)
	Techniques for increasing the capacity of wireless broadband networks: UK, 2012–2030 (2012)	Real Wireless	This report, which is related to the previous study by Real Wireless, considers the role of additional spectrum against the background of a wide range of other capacity-enhancing techniques – including LTE-Advanced and small cells
Denmark	*The future need for broadband frequencies in Denmark* (2011)	Analysys Mason for NITA	This report provides an analysis of future needs for broadband frequencies in Denmark. The report includes an estimate of the amount of spectrum required to provide fixed and mobile broadband services through wireless technology. This is meant to help NITA define its spectrum strategy though which it can facilitate the fulfilment of the government's objective of making 100Mbit/s broadband available to all citizens by 2020
France	*Etude des besoins en fréquences en France à l'horizon 2020* (2011)	TERA Consultants and ON-X	This report discusses drivers by application and attempts to quantify the amount of additional spectrum required in 2020
Global	*Global Market Forecast 2012-2031 (2012)*	Airbus	This report forecasts the future demand and traffic of air travel between 2012-2013
Global	*Aviation benefits beyond borders (2012)*	ATAG	This report analyses the economic benefits of aviation
EU-wide	*CEPT Report 014 (2006)*	CEPT	This report is in response to the mandate to: develop a strategy to improve the effectiveness and flexibility of spectrum availability for SRDs

Country	Study	Author	Outline
EU-Wide	*EUROCONTROL Long-Term Forecast, flight movements 2010-2030 (2010)*	EUROCONTROL	This report presents the 2010 update of EUROCONTROL Long-Term Forecast of IFR flight movements in Europe up to 2030. It focuses on developments after 2016.
EU-wide	*Intelligent Transport Systems in action (2010)*	European Commission	This report outlines an action plan and legal framework for the deployment of intelligent transport systems (ITS) in Europe.
EU-Wide	*Study analysing the current activities in the field of UAV (2007)*	Frost & Sullivan	This report analyses the current and future European UAV market situation and requirements
Global	*The total cost of ownership for embedded mobile devices (2010)*	Analysys Mason for the GSMA	This report examines the total cost of ownership of embedded mobile and machine-to-machine devices.
Global	*Global air navigation plan (2007)*	International Civil Aviation Organization	This report outlines the plan for continued safe, secure, efficient and environmentally sustainable air navigation.
Global	*Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace (2009)*	International Telecommunication Union	This report employs different methodologies to estimate the total spectrum requirements for unmanned aircraft in non-segregated airspace
Global	*Wide are multilateration, report on EATMP TRA 131/04 (2005)*	National Aerospace Laboratory NLR	The study addresses the advantages and disadvantages of WAM, analyses what performance can be achieved with this surveillance technique and what is required to provide a service at least equivalent to an MSSR/Mode S radar service.
UK	*Sustaining a thriving maritime sector (2012)*	Department for Transport and Maritime and Coastguard Agency	This report outlines potential policy actions to maintain effective ports for trade and travel.
Global	*Review of maritime transport (2012)*	United Nations Conference on Trade and Development	This review provides a comprehensive summary of global maritime transport.

Figure A.2: Studies relevant to non-EU countries [Source: Analysys Mason, 2012]

Country	Study	Author	Outline
USA	*Wireless Data: Supply and Demand* (2011)	Citigroup Global Markets	This study focuses on the spectrum distribution among US carriers and suggests that too much spectrum is controlled by companies not intending to fully use it
	Mobile broadband: the benefits of additional spectrum (2010)	FCC	This report seeks to demonstrate that mobile data demand is likely to exceed capacity under spectrum availability. The report argues that satisfying the demand for spectrum by making additional spectrum available is likely to generate considerable economic value
Australia	*Five-year spectrum outlook 2009–2013* (2009)	ACMA	This report examines issues pertinent to current and future demand for spectrum. The report also sets the work programs for ACMA in 2009–2013
Canada	*Study of Future Demand for Radio Spectrum in Canada 2011–2015* (2011)	Red Mobile and PA Consulting Group for Industry Canada	This study seeks to forecast future demand for both governmental and commercial services in the frequency range of 52MHz–38GHz. The study covers 15 categories of services and determines demand on the basis on modelling outputs, interaction with stakeholders and research

Figure A.3: Studies listed in the Tender documentation [Source: Tender documentation, 2012]

Country	Study	Author	Outline
EU-wide	*Opinion on Review of Spectrum Use* (2012)	RSPG	The opinion features an analysis undertaken by RSPG to assess demand for spectrum and the influence of technology trends on spectrum demand. The opinion also seeks to estimate the required supply of spectrum necessary to meet the demand and discusses the elements which should be considered in determining whether spectrum is used efficiently
EU-wide	*Commission paper on state of play of the RSPP negotiations and preparations for implementation of the spectrum inventory* (2011)	Radio Spectrum Committee	This paper sets an inventory of the existing spectrum uses which satisfies a number of objectives, amongst which identification of spectrum bands with sub-optimal spectral efficiency which could be improved, identification of spectrum bands suitable for re-allocation and sharing, analysis of the types of spectrum usage and others
EU-wide	*Final position paper on wireless broadband* (2009)	RSPG	The position paper identifies ways to maximise benefits of wireless broadband services to end users and to society overall. The paper includes a discussion on how EU member states and the EC can prepare to deal with lack of suitable spectrum for wireless broadband

Country	Study	Author	Outline
EU-wide	*Report on improving broadband coverage* (2011)	RSPG	This report discusses some of the main issues that EU-members experience in providing high-speed broadband services to all citizens and consumers. The report focuses on the role of wireless technologies in ensuring complete broadband coverage
EU-wide	*Opinion on best practices regarding the use of spectrum by some public bodies* (2009)	RSPG	The opinion features an assessment of best practices relevant to spectrum use by public bodies which are meant to increase the efficient use of spectrum
EU-wide	*Final report: optimising the public sector's use of the radio spectrum in the European Union* (2008)	WIK-Consult for the EC	This study seeks to promote better understanding of spectrum use by public sector bodies and to identify means of improving the efficiency of spectrum assignment and use
EU-wide	*Report and opinion on coordinated EU spectrum approach for scientific use of radio spectrum* (2006)	RSPG	This report provides an overview of the scientific use of spectrum and makes a distinction between active and passive radio techniques. The report also elaborates on the status of spectrum used for scientific services
EU-wide	*Opinion on the introduction of multimedia services in particular in frequency bands allocated to the broadcasting services* (2006)	RSPG	This paper reviews the regulatory context applicable to multimedia services and the various ways in which the introduction of multimedia services could be facilitated in bands allocated to broadcasting services. The paper also discusses the constraints in the broadcasting bands and how these could be addressed
UK	*Enabling UK growth – releasing public spectrum* (2011)	DCMS	This report outlines the plan of the UK government for fulfilling its commitment to making 500MHz available by 2020 after releasing public spectrum. The report reviews holdings of spectrum by the public sector, assesses market demand and establishes next steps
Americas	*Sustaining the mobile miracle: a 4G Americas blueprint for securing mobile broadband* (2011)	4G Americas	This report reviews the current state of mobile broadband in North and South America and suggests that additional spectrum is needed to prevent operators from facing spectrum shortage in the next five years. The report makes proposals to the stakeholders in the region top ensure the continued growth of mobile broadband

In compiling this bibliography we have tried to restrict the references to those which attempt to forecast the future demand for spectrum directly, or to forecast the major drivers in such a way that it will assist us in forecasting future demand for spectrum. There are, of course, many other studies and reports on spectrum matters (including the socio-economic benefits of spectrum, spectrum valuation, and spectrum allocation methods) that have been reviewed for the purpose of this study.

Annex B Detailed LTE technology trends

The various technologies used by LTE and LTE-Advanced also have a number of other spectrum uses, and so are discussed in more detail in the following sections.

B.1 MIMO

MIMO increases the throughput available with the same amount of spectrum, by employing multiple antennas at both the transmitting and receiving end. There are a number of possible configurations; for example, 2×2 indicates two transmitting antennas and two receiving antennas. In general, the higher the number of antennas in a configuration the better the performance. MIMO devices have been commercially available for some time, and some HSPA+ devices now use the technology; LTE is designed to build on this further.

Multiple antenna technology will gradually offer increasing spectrum efficiency through a steady advance in the number of antennas used both in the handset and at the terminal. As Figure B.1 below shows, increasing the number of antennas can provide a 22% increase in spectrum efficiency when considering 2×2, and a further 33% when considering 4×4.

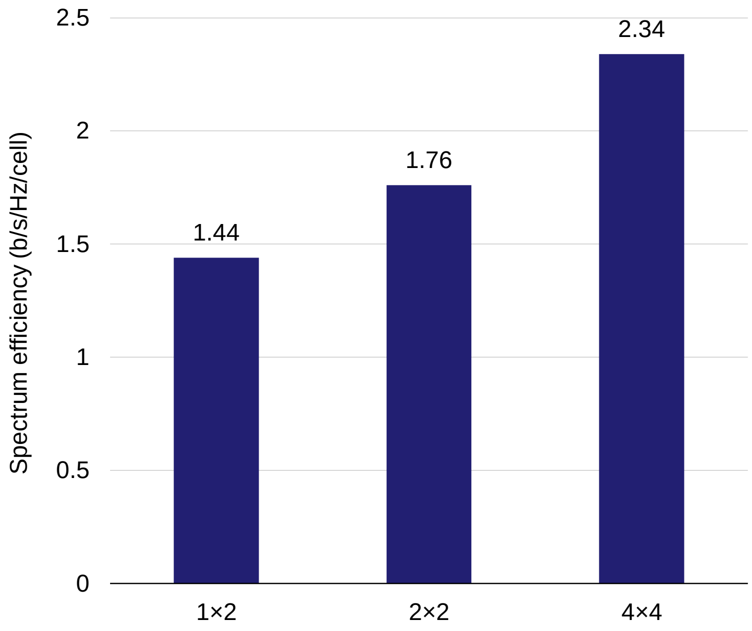


Figure B.1: Spectrum efficiency with varying MIMO antenna configurations for a 10MHz bandwidth with 64-QAM [Source: Analysys Mason, 2012]

LTE Release 8 is capable of 2×2 MIMO, with Release 10 not only capable of higher antenna orders (4×4 and 8×2), but also further advances such as multiple-user MIMO (MU-MIMO). This technique increases throughput over conventional single-user MIMO (SU-MIMO) by taking advantage of multiple users in a cell – it is able to re-use spectrum within a single cell to serve these multiple users, and in doing so can increase spectral efficiency. Both of these advances enable further increase in spectral efficiency over and above LTE Release 8.

The compound effects of different technologies can lead to significant increases in efficiency. This is illustrated in Figure B.2, which considers conventional SU-MIMO, as well as MU-MIMO and co-ordinated multipoint (CoMP, a method by which multiple cells can share the load of one user in order to increase throughput and efficiency). With a 4×4 antenna configuration MU-MIMO gives a 21% increase over SU-MIMO, while CoMP gives a 39% increase.

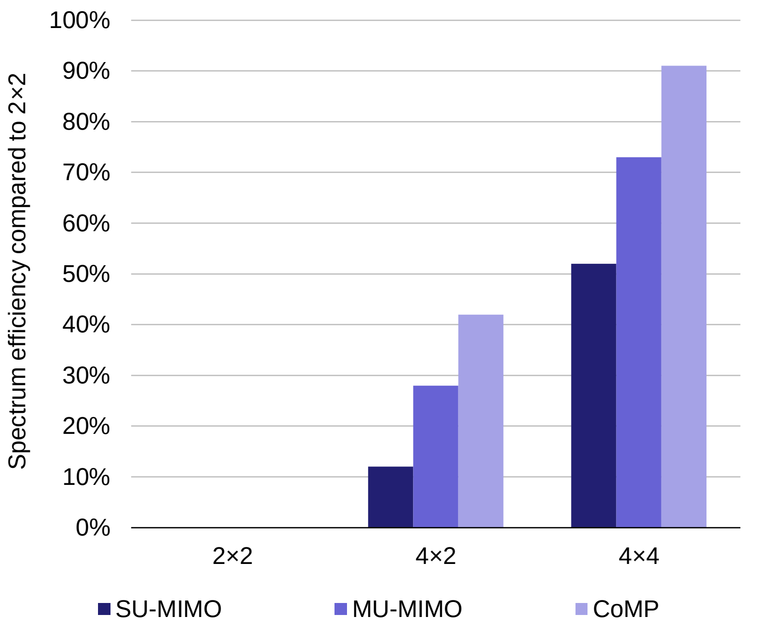


Figure B.2: Compound effect of antenna configurations and multi-user features [Source: 3GPP, Analysys Mason, 2012]

B.2 Enhanced modulation and coding efficiency

Adaptive modulation forms part of the LTE Release 8 standard, and allows the frequency encoding employed to vary depending on a number of factors (such as the quality of the radio channel), in order to optimise throughput. When conditions are optimal, a higher-order modulation can be used to maximise efficiency; conversely, when conditions deteriorate lower-order modulation is used. By reducing the total possible throughput, a higher-quality signal can be transmitted.

This technique takes advantage of the variable digital modulation technique, Quadrature Amplitude Modulation (QAM). This modulation system allows several lines of information to be transmitted across one signal. To do so it uses variations in magnitude and phase to provide a way of distinguishing between the different lines of information.

LTE supports modulation up to 64-QAM. It is unlikely that further advances will be made in this area, as the current application is approaching the theoretical (Shannon) limit of information that can be transmitted given certain conditions of noise and quality. However, LTE does still offer increases over methods that are currently in use; for example, HSPA uses 16-QAM.

B.3 Co-ordinated multi-point (CoMP)

The concept of CoMP is that cells share information on a user. By doing this they can either share the data between the cells or use information on the user to ensure reduced interference. In both cases increased network capacity can be achieved if neighbouring cells are able to share the required data. Figure B.3 below illustrates this concept.

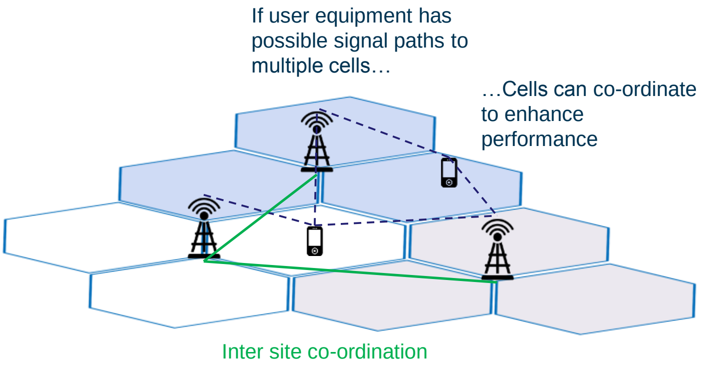


Figure B.3: Illustration of CoMP operation [Source: Analysys Mason, 2012]

For both LTE and LTE-Advanced two processes have been specified which can offer benefits in terms of network capacity. These processes are:

- **Joint processing** – when user equipment has multiple serving cells, user data can be transmitted (or received) in multiple locations. By enabling sharing of this data between these locations, capacity can be increased and interference reduced
- **Co-ordinated scheduling** – when user equipment has one serving cell no user data sharing is required. Scheduling information is shared between neighbouring cells with the aim of reducing or avoiding interference. This information could relate to power, load, beamforming weights, and so on. This scheme requires less sharing and processing than joint processing and so does not achieve such high capacity gains.

Figure B.2 above illustrates the benefits that CoMP techniques can provide in terms of spectrum efficiency compared to SU-MIMO and MU-MIMO LTE, for a range of antenna configurations.

Both of these schemes do, however, require a fast, low-latency interconnect between sites (typically fibre or microwave), as well as creating the need for additional data processing associated with the extra traffic. As such, the limit to the benefit is defined by the quality of the network itself.

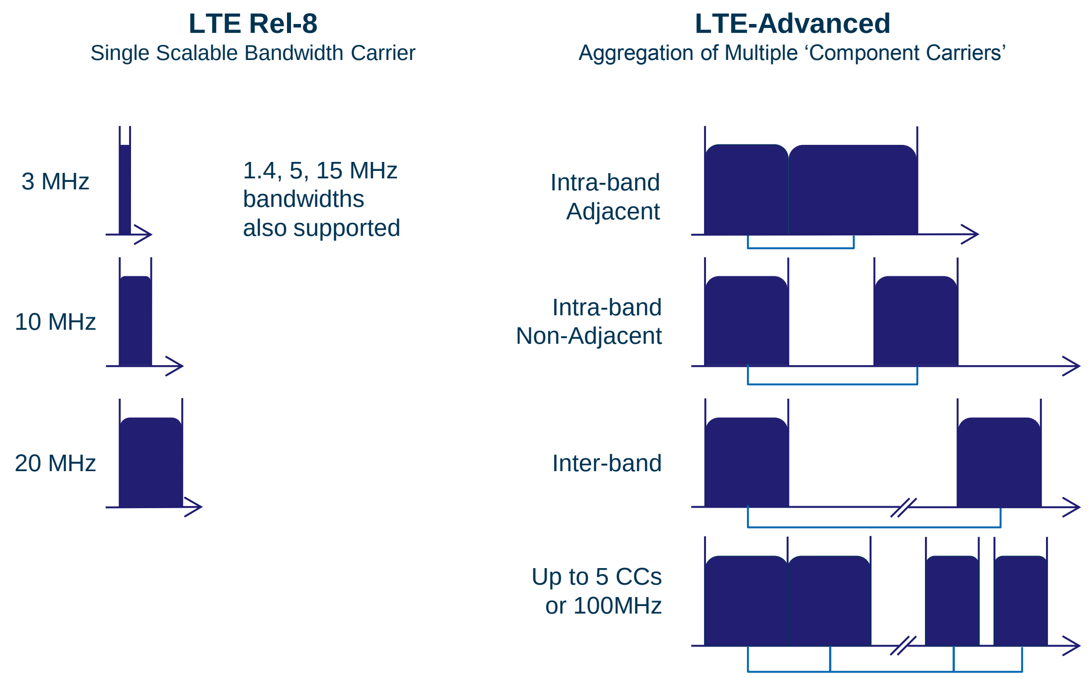
B.4 Carrier aggregation

Carrier aggregation is a method of maximising use of the bandwidth that is available for LTE At present, LTE works on carriers using contiguous, scalable bandwidths. These carriers are of the following specified widths; 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz; as such to achieve its maximum theoretical downlink capacity LTE must use the maximum 20MHz of bandwidth.

However, due to the size and distribution of operators' spectrum holdings, a further increase in these standard bandwidths is not practical. For this reason, a method has been developed to enable the use of non-adjacent spectrum.

For LTE-Advanced, 3GPP has decided to aggregate multiple 'component carriers', instead of simply increasing single-carrier bandwidth. This enables aggregation over non-adjacent spectrum designations, thus giving much higher effective bandwidth. With up to five component carriers being supported by an LTE-Advanced terminal, an effective maximum bandwidth of 100MHz is possible. Figure B.4 below shows various scenarios for the application of carrier aggregation.

Figure B.4: Scalable and aggregated bandwidth examples [Source: Analysys Mason, 2012]

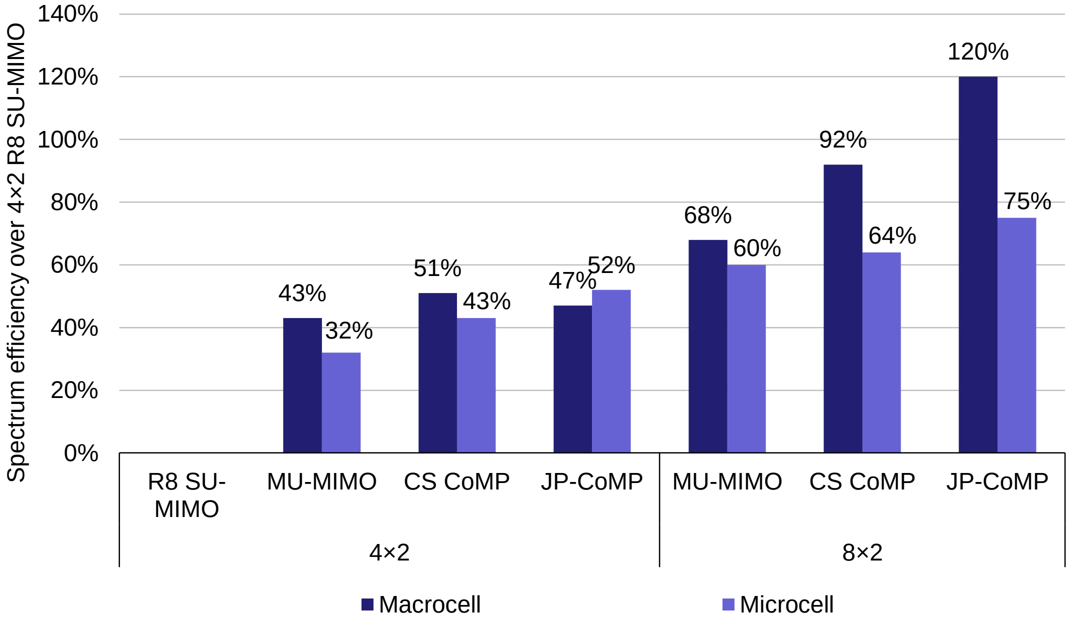


Implementation of this system of aggregation poses several challenges. Firstly, there needs to be co-ordination of the band combinations that terminals will support; this will need to be agreed by both mobile equipment and chipset manufacturers. In addition, increased regulation may be required to ensure that one operator does not have a significant advantage in terms of its spectrum portfolio. Finally, in order to achieve the maximum 100MHz aggregation, the user equipment would need to simultaneously transmit and/or receive five component carriers (i.e. 5×20MHz), which could be distributed in different frequency bands; this poses a significant challenge for manufacturers of radio frequency components that are used in terminals.

B.5 Summary

In summary, through a combination of the above technologies LTE and LTE-Advanced have the ability to dramatically increase the spectral efficiency of public mobile services. Figure B.5 shows the compound effects of some of these technologies over LTE Release 8 (i.e. SU-MIMO). It can be seen that the introduction of MU-MIMO would yield a theoretical 32% increase over SU-MIMO, rising to 60% with increased antenna configurations (8×2 as opposed to 4×2); and the use of CoMP would provide further improvements, potentially yielding an increase in spectrum efficiency of more than 100% compared to LTE.

Figure B.5: Benefits of LTE-Advanced over LTE [Source: 3GPP, Analysys Mason]



As an example of the effects of these technologies on one of our focus countries, Figure B.6 shows the projected evolution of average spectrum efficiency in the UK from 2010 to 2020. It shows that spectrum efficiency in the mobile sector is set to increase by some 190% between 2012 and 2020, with the main contributors being LTE and LTE-Advanced. This figure also demonstrates the variations in spectrum efficiency that will occur over time as the various technologies discussed here are released and adopted.

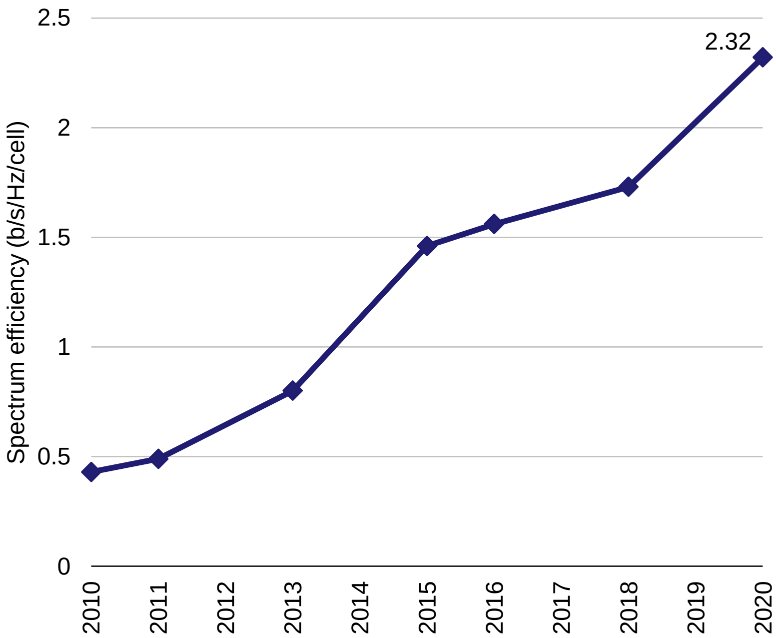


Figure B.6: Spectrum efficiency forecast for the UK [Source: 3GPP, Real Wireless, Analysys Mason, 2012]

Annex C Mapping of Inventory Application Groupings onto EFIS Applications (Level 2)

In line with the recommendations of the EC, we have used the 14 application groupings as defined in the WIK report *Inventory and review of spectrum use: Assessment of the EU potential for improving spectrum efficiency*.

Figure C.1 below includes a table mapping these 14 categories onto the existing EFIS level 2 applications as shown in Table 47 of the Spectrum Study report.

Figure C.1: Mapping of Inventory Application Groupings to EFIS Applications [Source: WIK-Consult, 2012]

Application grouping for efficiency analysis	EFIS Layer 2 applications
Aeronautical, maritime and civil radiolocation / navigation systems (AMCRN)	Aeronautical communications Aeronautical emergency Aeronautical navigation Aeronautical surveillance Aeronautical telecommand Aeronautical telemetry Aeronautical telemetry/telecommand GMDSS Land radionavigation Maritime communications Maritime navigation Radiolocation (civil) Satellite navigation systems
Broadcasting (Terrestrial)	Broadcasting (terrestrial)
BWA/cellular	Analogue cellular BWA Digital cellular MFCN TRA-ECS (Level 1)
Defence systems	Aeronautical military systems Land military systems Maritime military systems Meteorological aids (military) Radiolocation (military) Satellite systems (military) Telemetry (military) Telecommand (military) Telemetry/Telecommand (military)
Fixed links	Point-to-Multipoint Point-to-Point Telemetry (civil) Telecommand (civil) Telemetry/Telecommand (civil)
ITS	ITS Railway Applications RTTT

Application grouping for efficiency analysis	EFIS Layer 2 applications
Meteorology	Oceanographic buoys Sondes Weather radar Weather satellites Wind profilers
PMR/PAMR	Inland waterway communications Paging PMR / PAMR
PMSE	SAP/SAB and ENG/OB Radio microphones
Radio Astronomy	Continuum measurements Spectral line observations VLBI observations
Satellite systems (Civil)	Aeronautical satcoms Amateur-satellite Broadcasting-satellite receivers Earth exploration-satellite Feeder links FSS Earth stations Inter-satellite links MSS Earth stations Satellite navigation systems Standard frequency and time signal-satellite Space operations Space research
SRD	Active medical implants Alarms Inductive applications Model control Non-specific SRDs Radio microphones and ALD Radiodetermination applications RFID Tracking, tracing and data acquisition UWB applications Wireless audio applications
Wideband data transmission systems	Wideband data transmission systems

Annex D Glossary of terms

Abbreviation	Description
2G	Second-generation mobile service
3G	Third-generation mobile service
3GPP	Third-Generation Partnership Project
4G	Fourth-generation mobile service
5G	Fifth-generation mobile service
A2G	Air to ground
ADF	Automatic direction finder
ADS-B	Automatic dependent surveillance – broadcast
AEROMACS	Aeronautical mobile airport communications system
AGA	Air ground air
AIS	Automatic identification system
ALD	Assistive listening devices
AMCRN	Aeronautical, maritime and civil radiolocation / navigation systems
ASO	Analogue switch-off
Assignment (spectrum)	The assignment of designated spectrum to a licensee
ATAG	Air Transport Action Group
ATM	Air traffic management
B2M	Broadcast multimedia mobile
BBC	British Broadcasting Corporation
BLOS	Beyond line of sight
BNETZA	Bundesnetzagentur (German regulatory authority for industries: telecommunications, postal services, railways and electricity)
BT	British Telecom
BTS	Base transceiver station
BWA	Broadband wireless access
CAGR	Compound annual growth rate
CASCADE	Eurocontrol's ground and airborne surveillance programme
CCDP	Co-channel dual-polarisation
CCTV	Closed circuit television
CDMA	Code division multiple access
CEE	Central and Eastern Europe
CEPT	European Conference on Postal and Telecommunications Administrations
CIS	Commonwealth of Independent States
COTS	Commercial off the shelf
CRAF	Committee on radio astronomy frequencies
DA2GC	Direct air-to-ground communication

Abbreviation	Description
DAB	Digital audio broadcasting
DACS1	Digital aeronautical communication system type 1
DAE	Digital agenda for Europe
Designation (spectrum)	The designation of a harmonised band for a specific type of use
DFS	Dynamic frequency selection
DME	Distance Measuring Equipment
DMO	Direct mode operations
DMR	Digital mobile radio
dPMR	Digital private mobile radio
DSL	Digital subscriber line
DSO	Digital switchover
DSSS	Direct-sequence spread-spectrum
DTH	Direct-to-home
DTT	Digital terrestrial television
DVB	Digital video broadcasting
DVB-H	Digital video broadcasting – handheld
DVB-NGH	Digital video broadcasting – next-generation handheld
DVB-T	Digital video broadcasting – terrestrial
DVB-T2	Digital video broadcasting – terrestrial (second generation)
EC	European Commission
ECC	Electronic Communications Committee
ECO	European Communications Office
ECTS	European credit transfer and accumulation system
EDGE	Enhanced data rates for GSM evolution
EFIS	ECO frequency information system
EHS	Mode S Enhanced (aeronautical surveillance system)
ELS	Mode S Elementary (aeronautical surveillance system)
eMBMS	Evolved Multimedia Broadcast / Multicast Service
ERP	Effective radiated power
ERTMS	European Rail Traffic Management
ESA	European Space Agency
ETCS	European traffic control system
ETSI	European Telecommunications Standards Institute
ETSO	European Technical Standard Order
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUROCONTROL	European Organisation for the Safety of Air Navigation
EUTC	European Utilities Telecom Council
FAA	Federal Aviation Administration (USA)
FAT	Frequency allocation table

Abbreviation	Description
FCC	Federal Communications Commission
FD	Frequency division
FDD	Frequency division duplex
FHQ	Force headquarters
FHSS	Frequency-hopping spread-spectrum
FSS	Fixed satellite services
FTA	Free to air
FTK	Freight tonne kilometre
FWA	Fixed wireless access
GAW	Global Atmosphere Watch
GBP	Pound Sterling
GCW	Global Cryosphere Watch
GDDN	Galileo data dissemination network
GMDSS	Global maritime distress and safety system
GNSS	Global navigation satellite systems
GOS	Global observing systems
GPRS	General packet radio service
GPS	Global positioning system
GSA	GNSS Supervisory Authority
GSM	Global System for Mobile Communications
GSMA	GSM Association
GSM-R	Global System for Mobile Communications – Railway
HAN	Home area network
HD	High definition
HDTV	High definition television
HEVC	High-efficiency video coding (video encoding standard)
HF	High frequency
HSPA	High-speed packet access
IAAF	International Association of Athletics Federations
IATA	International Air Transport Association
IBW	In-building wireless
ICAO	International Civil Aviation Organization
IEM	In-ear monitor
IFR	Instrumental flight rules
IMF	International Monetary Fund
IMO	International Maritime Organization
IMT-2000	International Mobile Telecommunications – 2000
IPTV	Internet protocol television
ISR	Integrated services router
ITS	Intelligent transport system

Abbreviation	Description
ITU	International Telecommunication Union
LAN	Local area network
LBT	Listen before talk
LDACS	L-band digital aeronautical communication system
LEWP	Law Enforcement Working Party
LOS	Line of sight
LSA	Licensed shared access
LTE	Long-term evolution
LTE-A	Long-term evolution – advanced
M2M	Mobile to mobile
MAC	Media Access Control layer
MBAN	Medical body area network
MET	Meteorology
MFCN	Mobile/fixed communications networks
MFN	Multi-frequency network
MIMO	Multiple-input and multiple-output
M-LNB	Multi-Input Element Low Noise Block
MNO	Mobile network operator
MPEG-2	Video encoding standard (H.222/H.262)
MPEG-4	Video encoding standard (AVC/H.26)
MS	Mobile station
MSS	Mobile satellite service
MU-MIMO	Multi-user multiple-input and multiple-output
MUX	Multiplex
MVNO	Mobile virtual network operator
MWC	Mobile World Congress
NATO	North Atlantic Treaty Organization
NDB	Non-directional Beacon
NLoS	Non-line-of-sight
NRA	National regulatory authority
NXDN	A common air interface technical protocol for mobile communications
OB	Outside broadcasting
OFDMA	Orthogonal frequency-division multiple access
OHQ	Operational headquarters
OTT	Over the top
PAMR	Public access mobile radio
PC	Personal computer
PIR	Passive infrared
PMR	Private mobile radio
PMSE	Programme making and special events

Abbreviation	Description
PPDR	Public protection and disaster relief
QAM	Quadrature amplitude modulation
QLoS	Quasi-line-of-sight
QoS	Quality of service
R&D	Research and development
RAS	Radio Astronomy Service
RCEG	Radio Communication Expert Group
RFID	Radio frequency identification
RLAN	Radio local area network
RPAS	Remotely piloted aircraft systems
RPK	Revenue passenger kilometre
RSC	Radio Spectrum Committee
RSPG	Radio Spectrum Policy Group
RSPP	Radio Spectrum Policy Programme
SAB	Services ancillary to broadcasting
SAP	Services ancillary to programme
SBB	Spot beam
SCADA	Supervisory control and data acquisition
SD	Standard definition
SDTV	Standard-definition television
SES	Single European Sky
SESAR	Single European Sky ATM Research
SFN	Single-frequency network
SNR	Signal-to-noise ratio
SOLAS	Safety of life at sea
SPI-IR	Surveillance performance and interoperability implementing rule
SRD	Short-range device
SSR	Secondary surveillance radar
SST	Spread spectrum transmission
STB	Set top box
SU-MIMO	Single-user multiple-input and multiple-output
TACAN	Tactical Air Navigation
TCO	Total cost of ownership
TD	Time division
TDD	Time division duplex
TD-LTE	Time-division long-term evolution
TEDS	TETRA enhanced data services
TETRA	Terrestrial trunked radio
TMC	Traffic message channel
TPMS	Tyre pressure monitoring systems

Abbreviation	Description
TV	Television
UAS	Unmanned aeronautical system
UAV	Unmanned aeronautical vehicle
UHD	Ultra high definition
UHDTV	Ultra-high-definition television
UHF	Ultra-high frequency
UK	United Kingdom
UMTS	Universal mobile telecommunications system
UNCTAD	United Nations Conference on Trade and Development
USA	United States of America
USD	United States Dollar
UWB	Ultra wideband
V2I	Vehicle to infrastructure
V2V	Vehicle-to-vehicle
VHF	Very high frequency
VLBI	Very long baseline interferometry
VOD	Video on demand
VSAT	Very small aperture terminal
WAIC	Wireless Avionics Intra-Communications
WAM	Wide-area multilateration (aeronautical surveillance system)
WBA	Wireless Broadband Alliance
WFA	Wi-Fi Alliance
WHYCOS	World Hydrological Cycle Observing System
WIGOS	World Meteorological Organization Integrated Global Observing System
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless local area network
WMO	World Meteorological Organization
WRC	World Radiocommunications Conference
XPIC	Cross-polarisation interference cancellation

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