Economic benefits from making the 2.7-2.9GHz band available for mobile broadband services in Western Europe

Report for the GSM Association

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0 Executive Summary

This report has been prepared by Aetha Consulting Limited (Aetha) for the GSM Association (GSMA) as a summary of an assessment we have undertaken on the potential economic benefits arising from the use of the 2.7-2.9GHz band for mobile broadband services in Western Europe[1].

0.1 Background

The rapid take-up and usage of mobile broadband services is set to continue with the introduction of LTE mobile technology, which will provide sufficiently high data rates and low latency to reliably support applications such as video streaming. The challenge faced by network operators is to provide sufficient network capacity to support the demand from consumers for these services.

A key part of the solution is identifying new spectrum bands for mobile operators to make use of. As a consequence, the main agenda item at the next World Radiocommunications Conference (WRC-15) is to consider new spectrum bands for mobile. In its Radio Spectrum Policy Programme[2] the European Union has set the European Commission the target of identifying 1200MHz of spectrum (including the existing harmonised bands) to support the growth in wireless broadband traffic.

A pilot inventory of spectrum use[3] undertaken on behalf of the European Commission identified that the intensity of usage of the 2700-2900MHz band, which is currently allocated to aeronautical radio-navigation services (primary allocation) and to radio location services (secondary allocation), varies considerably across the European Union and (from a technical spectral efficiency perspective) is underutilised in many countries. This band is also in close proximity to the existing IMT-2000 extension band (2500-2690MHz) which has been assigned in most EU countries to mobile operators who are planning to use it for the deployment of LTE technology.

For these reasons, the GSM Association considers the 2.7-2.9GHz band as a potential candidate band which could help to provide the future mobile data network capacities that are required and wishes to understand the economic case for making this spectrum available for mobile broadband services, on the assumption that existing users of the spectrum can be migrated to another frequency band.

The objective of this study is therefore to make an initial estimation of the overall economic benefits that would arise in Western Europe as a result of making the 2.7-2.9GHz band available for mobile broadband services. Essentially this involves the estimation of the benefits of using the 2.7-2.9GHz band for mobile broadband services, less the costs of migrating the existing aeronautical radars to a new frequency band.

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1 Within this report Western Europe refers to Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

2 '*Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multi-annual radio spectrum policy programme*', Official Journal of the European Union, 21 March 2012.

3 '*Inventory and review of spectrum use: Assessment of the EU potential for improving spectral efficiency*', WIK-Consult study for the European Commission, 11 September 2012.

0.2 Approach to assessment of economic benefits

To assess the economic benefits from making the 2.7-2.9GHz band available for mobile broadband services, we compare the cost of relocating radars operating in the band to alternative frequencies, as well as mitigating interference that would occur from mobile use of the band, against the benefits of the band to mobile services.

In Western Europe the 2.7-2.9GHz band is currently allocated to aeronautical radio-navigation services (primary allocation) and to radio location services (secondary allocation), with usage of the band varying considerably across Western Europe. There are currently four types of radar operating in the 2.7-2.9GHz band in Western Europe:

- civilian Air Traffic Control (ATC) radars
- military ATC radars
- mobile bird-strike radars, designed to detect the flight of birds, which may collide with aeroplanes
- meteorological radars.

A study for the European Commission[4] details the number of civilian ATC radars operating in the 2.7-2.9GHz band for countries within the European Union, with a total of 112 civilian ATC radars operating in the band in Western Europe. To include countries in Western Europe outside of the European Union we have scaled up with population.

An Ofcom study[5] quotes the number of military radars in the UK operating between 2.7GHz and 3.1GHz as 35. We understand that the majority of these radars operate in the 2.9-3.1GHz band and assume 30% operate in the 2.7-2.9GHz band. To estimate the total military radars in Western Europe we have scaled up from the UK numbers by military expenditure. In total this gives an estimate of around 48 military radars in Western Europe operating in the 2.7-2.9GHz band.

The Ofcom study[5] also states that there are two mobile bird-strike radars operating in the UK in the 2.7-3.1GHz range. To estimate the number of bird-strike radars in Western Europe we have scaled up by civilian ATC radar numbers, giving a total of six bird-strike radars in Western Europe.

There are only a small number of meteorological radars operating in the 2.7-2.9GHz band in Western Europe (11 in total)[6]. We do not have detailed information on whether these radars would need to be relocated to an alternative frequency band or on the costs involved if this relocation is required. Hence we have not included these radars in our main assessment, however a possible relocation of these radars is considered as part of our sensitivity analysis on the results of the study (further details are provided below).

We have developed a model that calculates the cost of relocating the other radars currently operating in the band to alternative frequencies. The numbers of each type of radar are combined with estimated costs for both development and deployment of a new technology over an estimated timescale to give an overall cost.

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4 '*Inventory and review of spectrum use: Assessment of the EU potential for improving spectral efficiency*', WIK-Consult study for the European Commission, 11 September 2012.

5 '*Coexistence of S Band radar systems and adjacent future services*', Ofcom, 11 December 2009.

6 '*Working Group SE of the Electronic Communications Committee SE 21*', CEPT Electronic Communications Committee, 3 March 2011.

The development and deployment costs are based on a study by BAE Systems for Ofcom[7]. Two new technologies are assumed to need to be developed; one for civilian ATC and bird-strike radars and one for military radars. It is assumed that five manufacturers would be funded to develop the technologies, with costs of EUR16.8 million per manufacturer per technology. The technologies are assumed to cost EUR3 million to deploy on each radar.

The range 2.9-3.1GHz, directly above the 2.7-2.9GHz band, is also currently allocated to radars in Western Europe. If the 2.7-2.9GHz band were to be made available to mobile services, then due to its proximity to the 2.7-2.9GHz band, there is potential for interference to and from mobile services. In this case, military ATC radars and land-based radars operating in the range 2.9-3.1GHz may require additional filters. The cost of installing new filters on these radars, estimated as EUR300 000 per radar based on an information notice from the Civil Aviation Authority[8], has been added to the total cost.

We have developed a separate model to calculate the benefits of the 2.7-2.9GHz band to mobile network operators (MNOs). This benefit arises from MNOs having to build fewer additional sites to carry traffic, if they have additional spectrum due to the availability of this band. We have calculated these network cost savings for a MNO in a theoretical Western European market. This operator is assumed to have one third of the market in a country with population 50 million and to currently have 10 000 sites.

We consider the difference in network costs for the theoretical MNO between two scenarios:

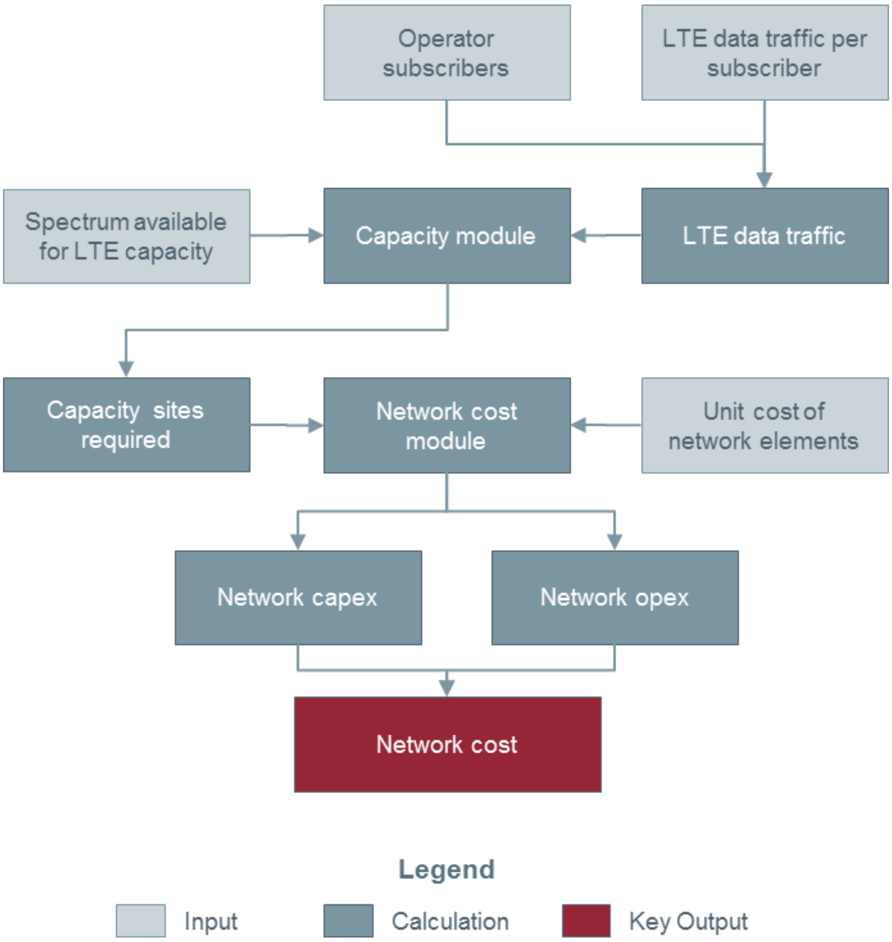
- A scenario where the 2.7-2.9GHz band is not available for mobile use
- A scenario where the band is available for mobile use once radars have been relocated from the band.

The calculation of network costs is illustrated in Figure 0-1 and discussed below.

7 '*Study into Spectrally Efficient Radar Systems in the L and S Bands*', BAE Systems study for Ofcom, May 2006.

8 '*Programme of Remediation for UK S-band (Primary) Radars*' (Information notice), Civil Aviation Authority, 24 October 2012.

Figure 0-1: Calculation flow of network capacity costs [Source: Aetha]



The model combines the population of the theoretical country with the operator's market share and a forecast of mobile SIM penetration to give the number of subscribers that the operator has each year. These subscriber numbers together with a forecast of LTE traffic per subscriber gives the total traffic the theoretical operator should carry on its network. The operator's traffic is then scaled to represent the downlink traffic in the busiest hour of the day on the busiest sector of each site, as this is the traffic that the operator will dimension their network based on.

The traffic along with available spectrum and sector capacity inputs feed into the capacity module, which calculates how many sites and carriers are required to hold the traffic. The cost of operating and building the sites is then calculated using forecasts for unit costs of various network elements.

A key input that drives these costs is the traffic forecast, for which we have combined forecasts from an ITU publication[9] and a UMTS Forum report[10]. The resulting forecast is shown below in Figure 0-2.

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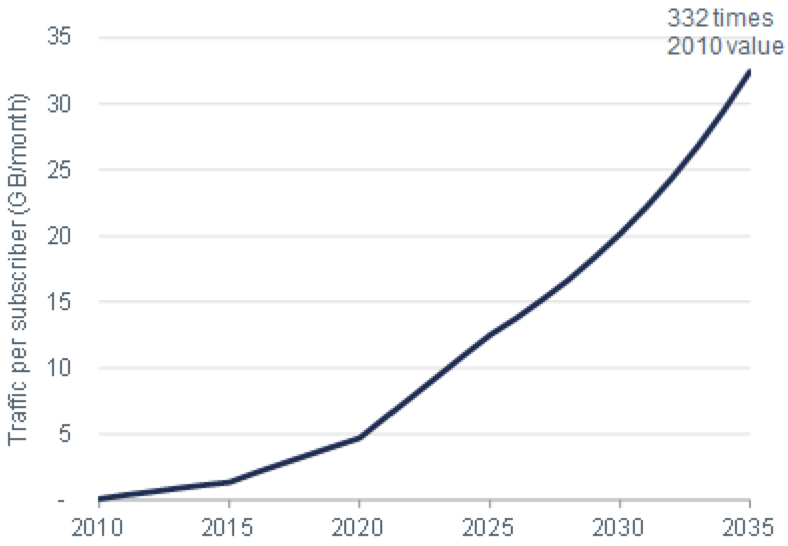
9 '*Meeting Report of SWG IMT.TRAFFIC at WP 5D #15*', ITU, 5 February 2013.

10 '*Mobile traffic forecasts 2010-2020 report*', UMTS Forum, January 2011.

Figure 0-2: Traffic forecast per SIM for theoretical Western European operator [Source: Aetha, based on forecasts from the ITU and UMTS Forum]



The network costs are calculated for the years 2015 to 2034, from when a decision on the band is likely to be announced (at WRC-15) to a likely expiry date of 2.7-2.9GHz band licences.

The network cost savings represent an increase in producer surplus, i.e. the profit earned by the producer of the service. In a competitive market, the MNOs would lower their prices in line with these cost savings, in order to retain market share. Thus, for each year of the modelling period, we transfer the gain in producer surplus to a gain in consumer surplus (i.e. the difference between consumers' valuation/willingness to pay for the service and the prices actually paid). To do this we assume that the producer surplus is the same in the scenario with the 2.7-2.9GHz band available for mobile services as the scenario where the band is not available for mobile services. Using forecast demand curves, we then estimate the number of subscribers that a decrease in price would produce and derive the consumer surplus.

The consumer surplus is calculated on a market level for the theoretical country and then scaled to Western Europe by population. The difference in consumer surplus between the scenarios with and without the 2.7-2.9GHz band available for mobile is then the total economic benefit of the band to mobile broadband services in Western Europe.

In order to compare the costs and benefits, the models both operate on an annual basis, with the costs and benefits both discounted to give net present values for 2015, to coincide with WRC-15 when any decision on the future use of the 2.7-2.9GHz band is likely to be made.

0.3 Cost of relocating radar from the band

The results of the calculation of the total cost of relocating radars from the 2.7-2.9GHz band and also installing additional filters on radars operating in the 2.9-3.1GHz band are shown below in Figure 0-3.

Figure 0-3: Radar cost results [Source: Aetha]

Type of cost	Number of radars affected	Net present value of costs (EUR m)
Relocation of civilian ATC and bird-strike radars	124	448
Relocation of military ATC radars	49	224
Additional filters to be installed	140	47
Total costs		718

As Figure 0-3 shows, the total cost is EUR718 million, with the majority (62%) of the costs being for the relocation of civilian ATC and bird-strike radars from the band.

We have performed sensitivity analysis on some of the key inputs and assumptions of the calculation of radar costs. The ranges of results for each sensitivity are shown below in Figure 0-4.

Figure 0-4: Summary of sensitivities on radar costs incurred if the 2.7-2.9GHz band is made available to mobile services [Source: Aetha]

Sensitivity	Net present value of costs (EUR m)
Base case	718
Military radar numbers scaled by civilian ATC radars	645
Military radar numbers scaled by population	792
Bird-strike radar numbers scaled by population	740
Military radars retuned to the 2.9-3.1GHz band	565
Meteorological radars need to be relocated from the band	949
Range of sensitivities	565 - 949

0.4 Economic benefits from use of the band for mobile broadband

The benefit to mobile broadband services in Western Europe of having access to the 2.7-2.9GHz band from 2021 is first calculated as a network cost saving for a theoretical Western European mobile operator. The estimated number of additional sites built by the theoretical operator with and without the 2.7-2.9GHz band are summarised in Figure 0-5 below.

Figure 0-5: Additional site build of the theoretical Western European operator [Source: Aetha]

Scenario	Number of sites built by the theoretical operator by 2035
Without the 2.7-2.9GHz band for mobile	1650
With the 2.7-2.9GHz band for mobile	800
Sites saved if the 2.7-2.9GHz band is available to the theoretical operator	850

As Figure 0-5 shows, the model estimates that the theoretical operator would have to build an additional 850 base station sites by 2035, if it did not have access to the 2.7-2.9GHz band.

The benefit of the 2.7-2.9GHz band to mobile broadband services in Western Europe is calculated from the network cost savings by converting the producer surplus to consumer surplus. In this study, we have estimated the economic benefits of the band to mobile services as EUR8143 million.

We have performed sensitivity analysis on some of the key inputs and assumptions of the calculation of the benefit of the band to mobile services. The range of results from this sensitivity analysis is displayed in Figure 0-6 below.

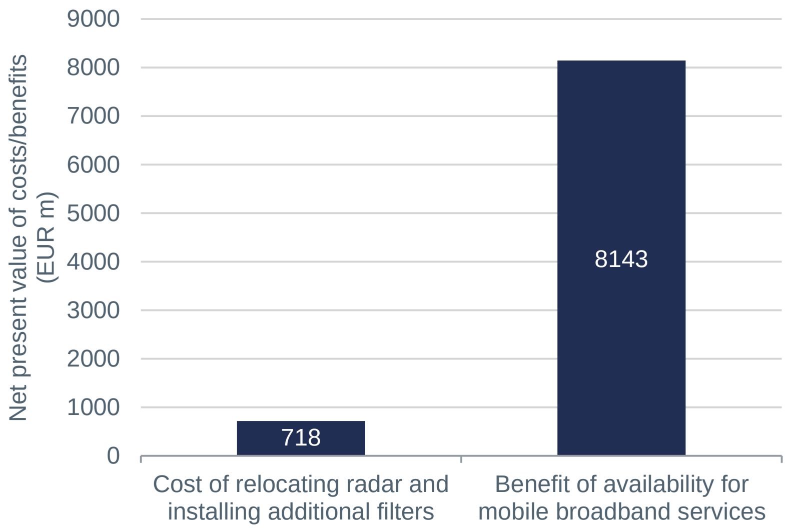
Figure 0-6: Summary of sensitivities on the benefit of the 2.7-2.9GHz band to mobile services [Source: Aetha]

Sensitivity	Net present value of benefits (EUR m)
Base case	8143
Availability of the 3.5GHz band for mobile services	3402
Higher traffic levels than expected (2× traffic by 2035)	21 524
Traffic levels based on extrapolation of Cisco forecast (see Section 4.4.2)	72 302
Lower long term spectral efficiency	11 541
Price elasticity of demand halved	6319
Price elasticity of demand doubled	25 841
Savings not passed on to consumers	5253
Timing of the availability of the band 2025	7362
Range of sensitivities	3402 - 72 302

0.5 Conclusions

The economic benefits of making the 2.7-2.9GHz band available to mobile broadband services in Western Europe is assessed by estimating the benefits of the band to mobile services and the costs to radar services if the band were to be made available to mobile services. A comparison of these is provided below in Figure 0-7.

Figure 0-7: Comparison of costs and benefits of making the 2.7-2.9GHz band available to mobile services in Western Europe [Source: Aetha]

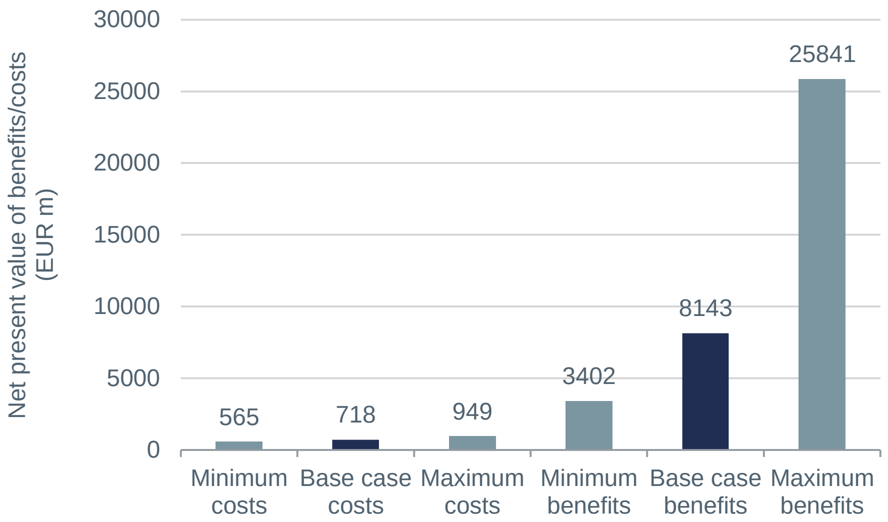


As shown in Figure 0-7, we have estimated the benefit of the 2.7-2.9GHz band to mobile services as EUR8143 million and the cost to radar services as EUR718 million. This suggests that the benefit of making the band available to mobile services is approximately 11 times the costs that would be incurred by doing so.

Sensitivity analysis on the timing of the availability of the band suggests that the earlier that the band is made available, the larger the economic benefits. Indeed, if availability were to be delayed from 2021 to 2025, then approximately 10% of the benefit to mobile services would be lost.

To provide an estimate of the range of possible values for the benefits and costs of making the 2.7-2.9GHz band available for mobile services in Western Europe, our assessment includes sensitivity analysis on some key inputs and assumptions. The ranges of estimates resulting from this sensitivity analysis are displayed below in Figure 0-8.

Figure 0-8:
Range of estimates for the benefits and costs of making the 2.7-2.9GHz band available for mobile broadband in Western Europe[11] [Source: Aetha]



As can be seen in Figure 0-8, although the ranges are significant in size, the minimum estimated benefit of the band to mobile services is significantly higher than the maximum estimated radar costs (approximately 3.6 times higher).

Thus the conclusion of this assessment is that, provided that a new frequency range can be found for the radars, making the 2.7-2.9GHz band available for mobile broadband in Western Europe would maximise the economic benefits from this frequency band.

This study is intended as an initial estimation of the economic benefits, and therefore more detailed studies could be undertaken in order to provide more accuracy. However, the estimate we have calculated for the benefits is significantly higher than our estimate of the costs. Thus, although additional information/detail may result in a change to the quantitative results, the qualitative conclusion is very likely to remain (i.e. the benefits will still outweigh the costs).

[11] Note that we have not included the sensitivity based on the Cisco forecast in this figure, for ease of reading.

1 Introduction

This report has been prepared by Aetha Consulting Limited (Aetha) for the GSM Association (GSMA) as a summary of an assessment we have undertaken on the potential economic benefits arising from the use of the 2.7-2.9GHz band for mobile broadband services in Western Europe[12].

1.1 Background

The rapid take-up and usage of mobile broadband services is set to continue with the introduction of LTE mobile technology, which will provide sufficiently high data rates and low latency to reliably support applications such as video streaming. The significant reductions in cost per bit arising from the introduction of new technologies enables these applications to be provided over mobile networks at prices attractive to consumers. The challenge faced by network operators is to provide sufficient network capacity to support the demand from consumers for these services. For example, the latest Cisco VNI network forecast[13] suggests that mobile data traffic in Western Europe will grow from 181 397 TB per month in 2012 to 1 384 072 TB per month by 2017 (a compound annual growth rate of 50%).

Part of the solution to carrying this huge increase in traffic lies in the use of new LTE technology, which is significantly more spectrally efficient than existing 2G and 3G technologies, another part of the solution lies in changing network architectures (e.g. wider introduction of small cells), but a key part of the solution is identifying new spectrum bands for mobile operators to make use of. As a consequence of this, the main agenda item at the next World Radiocommunications Conference (WRC-15) is to consider new spectrum bands for mobile, and in its Radio Spectrum Policy Programme[14] the European Union has set the European Commission the target of identifying 1200MHz of spectrum (including the existing harmonised bands) to support the growth in wireless broadband traffic.

A pilot inventory of spectrum use[15] undertaken on behalf of the European Commission identified that the intensity of usage of the 2700-2900MHz band, which is currently allocated to aeronautical radio-navigation services (primary allocation) and to radio location services (secondary allocation), varies considerably across the European Union and (from a technical spectral efficiency perspective) is underutilised in many countries. This band is also in close proximity to the existing IMT-2000 extension band (2500-2690MHz) which has been assigned in most EU countries to mobile operators who are planning to use it for the deployment of LTE technology.

For these reasons, the GSM Association considers the 2.7-2.9GHz band as a potential candidate band which could help to provide the future mobile data network capacities that are required to meet demand and wishes to understand the economic case for making this spectrum available for mobile broadband

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[12] Within this report Western Europe refers to Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

[13] '*Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017*', Cisco, 6 February 2013.

[14] '*Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multi-annual radio spectrum policy programme*', Official Journal of the European Union, 21 March 2012.

[15] '*Inventory and review of spectrum use: Assessment of the EU potential for improving spectral efficiency*', WIK-Consult study for the European Commission, 11 September 2012.

services, on the assumption that existing users of the spectrum (which includes both civil and military aeronautical radars) can be migrated to another frequency band.

The objective of this study is therefore to make an initial estimation of the overall economic benefits that would arise in Western Europe as a result of making the 2.7-2.9GHz band available for mobile broadband services. Essentially this involves the estimation of the benefits of using the 2.7-2.9GHz band for mobile broadband services, less the costs of migrating the existing aeronautical radars to a new frequency band.

1.2 Structure of this report

This report outlines the approach and findings of our study into the economic benefits of making the 2.7-2.9GHz band available to mobile broadband services in Western Europe. The remainder of this document is structured as follows:

- Section 2 presents the overall approach to assessing the economic benefits of making the band available
- Section 3 outlines the assessment of the costs of relocating radars that currently operate in the band, including the results of sensitivity analysis on key assumptions
- Section 4 outlines the assessment of the economic benefits of the band to mobile broadband services, including the results of sensitivity analysis on key assumptions
- Section 5 summarises the conclusions of the study.

In addition we have utilised the results of this study to undertake a high-level estimate of the potential value of the 2.7-2.9GHz band in the Rest of Europe[16]. This should be treated as an indicative estimate as this has been calculated through a simple "extension" of the results for Western Europe. The methodology used for and the results of this assessment are presented in Annex A.

[16] Within this report the Rest of Europe refers to Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Kosovo, Latvia, Lithuania, FYR Macedonia, Malta, Montenegro, Poland, Romania, Serbia, Slovakia and Slovenia.

2 Approach to assessment of economic benefits

In this section we provide an overview of the approach taken in our study into the economic benefits of making the 2.7-2.9GHz band available for mobile broadband services in Western Europe. The study involves calculating estimates of both the economic benefit of the band to mobile broadband services and the cost of relocating radars that currently operate in the band. We begin with a discussion of the overall approach taken for both issues, before providing details of parameters and assumptions that are relevant to both calculations.

A more detailed discussion of the approach to calculating the costs involved for relocating radars from the band is provided in Section 3, whilst more detail on the calculation of the benefits of the band for mobile services is provided in Section 4.

2.1 Overall approach

To assess the economic benefits from making the 2.7-2.9GHz band available for mobile broadband services, we compare the cost of relocating radars operating in the band to alternative frequencies, as well as the cost of mitigating interference that would potentially occur as a result of mobile use of the band, against the benefits of this additional spectrum band being available for mobile services.

2.1.1 The cost of relocating radars from the band

Currently the 2.7-2.9GHz band is utilised by radar services in Western Europe. This includes both civilian Air Traffic Control (ATC) radars and military radars. In addition there are mobile 'bird-strike' radars operating in the band and in a few countries also meteorological radars. In order for the band to be utilised by mobile services, the civilian, military and bird-strike radars should be relocated to operate on alternative frequencies, to avoid interference both from mobiles to radars and vice versa. This relocation would involve the development of new designs of radars, as well as the cost of deploying this new technology. As there are only a few meteorological radars operating in the band in Western Europe, these may not need to be relocated.

We have developed a model that calculates the cost of relocating the radars currently operating in the band to alternative frequencies. The numbers of each type of radar are combined with estimated costs for both development and deployment of a new technology over an estimated timescale to give an overall cost.

Radars operating above the band, in the frequency range 2.9-3.1GHz, may receive interference from mobile services that would be operating in the 2.7-2.9GHz band. The cost of installing new filters on these radars has been added to the total cost.

The approach to calculating these costs is discussed in more detail along with the findings in Section 3.

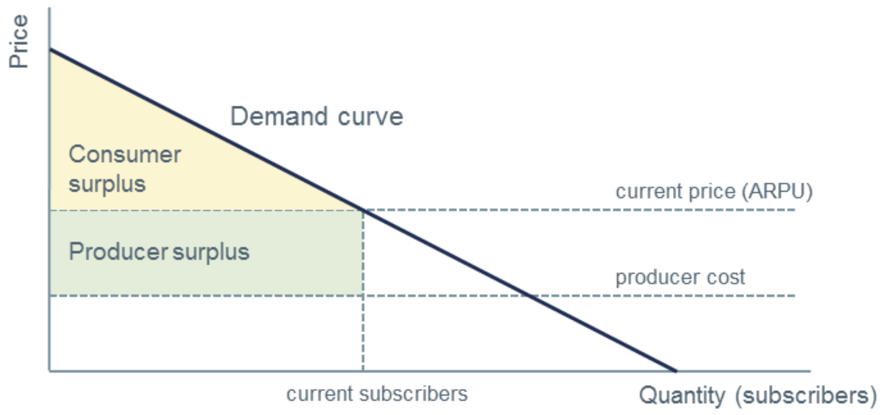
2.1.2 The benefits of the band to mobile services

If the 2.7-2.9GHz band were available to mobile network operators (MNO), it would allow for higher capacities on sites. This would allow MNOs to carry more traffic on their existing sites and on newly built sites, hence decreasing the need for new sites to cope with increasing traffic levels. This leads to cost savings for the MNO from the building and operating of fewer new sites. Thus the producer surplus, i.e. the profit earned by the producer of the service, is increased.

We have calculated the cost savings to a MNO in a theoretical Western European market. For this, we consider the difference in network costs for the MNO between a scenario where the 2.7-2.9GHz band is not available for mobile use and a scenario where the band is available for mobile use. These costs are calculated on an annual basis for the years 2015 to 2034, from when a decision on the band is likely to be announced (at WRC-15) to a likely expiry date of 2.7-2.9GHz band licences (15 years after radar can be relocated from the band).

In a competitive market, the MNOs would lower their prices in line with these cost savings, in order to retain market share. Thus, for each year of the modelling period, we transfer the gain in producer surplus to a gain in consumer surplus (i.e. the difference between consumers' valuation/willingness to pay for the service and the prices actually paid). The concepts of producer and consumer surplus are illustrated in Figure 2-1 below.

Figure 2-1: Illustration of consumer and producer surplus [Source: Aetha]



The demand curve in Figure 2-1 represents the number of subscribers willing to pay the corresponding price for the service (in this case a mobile SIM). Thus the consumer surplus is approximated by the area between the demand curve and the current price of the service (which is equivalent to the current ARPU).

The consumer surplus is calculated on a market level for the theoretical country and then scaled to Western Europe by population. The difference in consumer surplus between the scenarios with and without the 2.7-2.9GHz band available for mobile is then the total economic benefit of the 2.7-2.9GHz band to mobile broadband services in Western Europe.

The approach to calculating the network savings and the resulting consumer surplus is discussed in more detail along with the findings in Section 4.

2.2 Parameters common to both models

In order to compare the costs and benefits, there needs to be a consistency in some financial parameters which are common to both calculations:

- The costs and benefits are both discounted to give net present values for 2015, to coincide with WRC-15, when the decision on the future use of the band is expected.
- A social discount rate of 3.5% has been used, based on academic publications and the European Commission's recommendations:

- A paper from 2006[17] argues that the social discount rate for countries in the European Union should be between 3% and 4%
- The European Commission has recommended using a social discount rate of 3.5% for European Union countries between 2007 and 2013, except for the 'Cohesion' countries[18], where a rate of 5.5% is recommended[19].

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17 '*Social discount rates for the European Union*', D. Evans, 31 October 2006.

18 The Cohesion countries comprise Greece, Ireland, Portugal and Spain.

19 '*Guidance on the Methodology for carrying out Cost-Benefit Analysis*', European Commission, August 2006.

3 Cost of relocating radar from the band

In this section we discuss the approach and findings of the assessment of the costs that would be incurred in relocating radars from the 2.7-2.9GHz band to alternative frequencies. We start with some background on radars in Western Europe, before discussing our sources and assumptions for radar numbers for both civilian and military radars. Then we discuss in detail the approach to calculating the total cost of relocating the radars from the band. Finally in this section we present our findings on the costs involved and also present sensitivity analysis on some key assumptions.

3.1 Background

In Western Europe the 2.7-2.9GHz band is currently allocated to aeronautical radio-navigation services (primary allocation) and to radio location services (secondary allocation). The usage of the band varies considerably across the region, with some countries making more use of other bands for radars (e.g. the so-called 'L-band'), or having less need for radars. There are currently four types of radar operating in the 2.7-2.9GHz band in Western Europe:

- Civilian Air Traffic Control (ATC) radars
- Military ATC radars
- Mobile bird-strike radars, designed to detect the flight of birds, which may collide with aeroplanes
- Meteorological radars.

In order for the band to be available for mobile use, nearly all of these radars will need to be relocated to alternative frequencies, in order to prevent interference.

A small number of the military radars are particularly expensive special radars (for example large phased array radars, used for monitoring incoming missiles etc.) and would incur very large costs to relocate to an alternative frequency. For these radars it would be more beneficial to set up exclusion zones around the radar for mobile services in the band. As these radars are very likely to be in areas with low populations, and hence have a very minor effect on the benefit of the band to mobile services, we have not included this in our assessment.

The meteorological radars are only operating in the 2.7-2.9GHz band in three countries in Western Europe (France, Greece and Italy). These are used to locate and track precipitation. We do not have detailed information on whether these radars would be relocated to an alternative frequency band, if the 2.7-2.9GHz band were to be made available to mobile services, or of the costs that would be involved. In view of this, and since there are only a few of these in Western Europe (11 in total)[20], we have not included any cost of relocation for these radars in our main results. An estimation of the costs involved if these radars were relocated to an alternative band has been considered as a sensitivity in Section 3.5.4.

The range 2.9-3.1GHz, directly above the 2.7-2.9GHz band, is also currently allocated to radars in Western Europe. This range is used for military ATC radars and also maritime radars, both land-based and shipborne. Due to its proximity to the 2.7-2.9GHz band, there is potential for interference to and from mobile services, should they be allocated to the 2.7-2.9GHz band. Indeed, due to the proximity with the 2.6GHz band, which is used by mobile services in Western Europe, many radars operating between 2.7 and

[20] '*Working Group SE of the Electronic Communications Committee SE 21*', CEPT Electronic Communications Committee, 3 March 2011.

3.1GHz have had filters installed to mitigate interference. If the 2.7-2.9GHz band were to be made available to mobile services, then radars operating in the range 2.9-3.1GHz may require additional filters.

We have assumed that shipborne maritime radars would not require these filters. Currently, some of these radars are not allowed within five nautical miles of the UK coastline, in order to prevent interference to civilian ATC radars. A similar, perhaps larger, exclusion zone could mitigate any interference to and from mobile services. This issue would need to be investigated further, though the effect on this assessment is likely to be small, and hence it has not been considered further.

As there are military ATC radars operating in the frequency range 2.9-3.1GHz, it may be possible that many radars operating in the 2.7-2.9GHz band could be retuned to work on these higher frequencies (provided that there is enough spectrum available in the range). This would be cheaper than deploying a new technology for these radars. The additional costs in this case would come from:

- installing new filters on these radars, to prevent interference from mobile services that will be operating in the 2.7-2.9GHz band
- retuning costs for these radars and potentially all military radars already operating in the range 2.9-3.1GHz, as to accommodate these radars the range 2.9-3.1GHz may need to be re-planned.

The possibility of retuning the military spectrum operating in the 2.7-2.9GHz band has been considered as a sensitivity in Section 3.5.3.

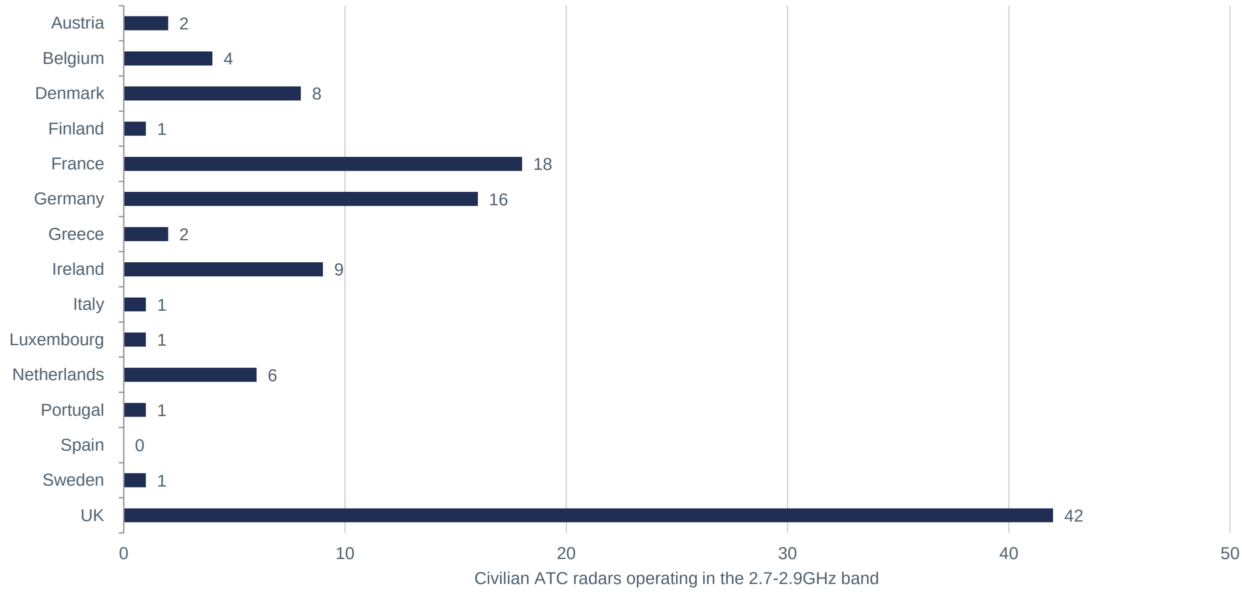
3.2 Radar numbers in Western Europe

In order to calculate the cost of relocating radars from the band we require the number of radars that currently operate in the band in Western Europe. We estimate the number of radars for each of the three types operating in the band (excluding meteorological radars); civilian ATC, military and bird-strike. We also estimate how many additional filters would be required to prevent interference from mobile services, if they were to utilise the 2.7-2.9GHz band.

Civilian ATC radar numbers for radars operating in the 2.7-2.9GHz band are detailed for countries in the European Union in a study for the European Commission[21]. The radar numbers for those countries in Western Europe are shown below in Figure 3-1. As can be seen from the figure, there are a total of 112 civilian ATC radars operating in the band in Western Europe within countries in the European Union. To include countries in Western Europe outside of the European Union we scale up the number of radars by population. This gives an estimate of 118 civilian ATC radars operating in the 2.7-2.9GHz band in Western Europe.

21 '*Inventory and review of spectrum use: Assessment of the EU potential for improving spectral efficiency*', WIK-Consult study for the European Commission, 11 September 2012.

Figure 3-1: Civilian ATC radars operating in the 2.7-2.9GHz band [Source: WIK-consult[21]]



We note that a relatively large proportion of the civilian ATC radars in Western Europe operate in the UK. We understand that the ATC radars are deployed at airports with large volumes of air traffic, of which the UK has a relatively large number. Further, some countries utilise individual radars for both air traffic control and military use and do not count these as ATC radars (hence some countries in Figure 3-1 are shown as having no ATC radars). Also, use of other bands for radars varies significantly between these countries.

The number of military radars in the UK operating between 2.7GHz and 3.1GHz is quoted as 35 in an Ofcom study into the potential mitigation of interference in these frequencies from services operating in neighbouring bands[22]. We understand that the majority of these radars operate in the 2.9-3.1GHz band, so we assume 70% of them operate in this frequency range. The remaining 30% would be relocated to an alternative frequency band. To estimate the total military radars in Western Europe we have scaled up from the UK numbers by military expenditure. For this we have used 2012 military expenditure data from SIPRI[23]. In total this gives an estimate of around 48 military radars in Western Europe operating in the 2.7-2.9GHz band.

The Ofcom study[22] also states that there are two mobile bird-strike radars operating in the UK in the 2.7-3.1GHz range. We have assumed that both would need relocating to an alternative spectrum band. To estimate the number of these bird-strike radars in Western Europe we have scaled up by civilian ATC radar numbers. This gives a total of six bird-strike radars in Western Europe that would need relocating to alternative bands.

The military ATC and land-based maritime radars operating in the 2.9-3.1GHz band are assumed to need additional filters installed, to prevent interference from mobile services. As mentioned above, we have assumed that 70% of the UK military ATC radars operating between 2.7 and 3.1GHz operate in the top

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22 '*Coexistence of S Band radar systems and adjacent future services*', Ofcom, 11 December 2009.

23 '*The SIPRI military expenditure database 1988-2012*', Stockholm International Peace Research Institute.

half of this range. We scale these to Western Europe by military spending, to give 112 military radars requiring filters. In the Ofcom study[22], the number of land-based maritime radars operating in the 2.9-3.1GHz band is stated as four. These are scaled up with population to give an estimate of 26 land-based radars in Western Europe requiring filters. Thus a total of 138 additional filters are estimated to be required.

3.3 Methodology for calculating radar relocation costs

In order to relocate radars to alternative bands a new technology would need to be developed. We assume that separate technologies would need to be developed for both civilian (ATC and bird-strike) and military radars. The development costs have been taken from a BAE Systems study for Ofcom into the spectral efficiency[24] of frequencies used for radar, including the 2.7-2.9GHz band. This study suggests development costs of GBP14 million (approximately EUR16.8 million), with a development period (i.e. time to develop the technology) of five years. As governments would like several competing manufacturers of this technology, we have multiplied these costs (for both civilian and military radars) by a number of competing manufacturers, assumed to be five.

If the 2.7-2.9GHz band were to be made available to mobile services, then development is expected to begin in 2015, after the decision on the band has been announced at WRC-15. We assume that the majority of the cost (60%) of this development would take place in 2017-18, with costs increasing after an initial planning period, with the development being completed in 2019.

The technology then needs to be deployed on each radar. We assume that 50% of the radars can be upgraded in 2019, once technology development is almost complete, whilst the other 50% require the extra small amount of technology development and are upgraded in 2020. This allows for the band to be used for mobile broadband services from 2021.

The BAE Systems study for Ofcom[24] provides an estimate of the costs of deployment of the new technology at GBP2.5 million (approximately EUR3 million). As with the development costs, we assume the same deployment costs for military and civilian radars. Half of these costs have been inflated, to reflect the assumed labour component of the deployments. An inflation rate of 2% has been used, in line with current European forecasts[25].

In order to estimate the cost of installing additional filters for radars operating in the 2.9-3.1GHz range, we have made use of information on the current remediation programme for radars operating in the 2.7-2.9GHz range in the UK. These require similar protection from interference from mobile services operating in the 2.6GHz band. An information notice from the Civil Aviation Authority[26] provides details of the remediation. Whilst specific costs will vary by radar, a cap of GBP300 000 (approximately EUR360 000) has been imposed, to cover 80% of the remediation for an Air Navigation Service Provider (which owns and maintains civilian ATC radars). We have therefore assumed a cost of EUR360 000 per filter installation, with installation taking place in 2019 and 2020. Note that as we are using this cap as an

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24 '*Study into Spectrally Efficient Radar Systems in the L and S Bands*', BAE Systems study for Ofcom, May 2006.

25 For example, the ECB forecasts an inflation rate of 2% for the next 5 years (see **http://www.ecb.int/stats/prices/indic/forecast/html/table_hist_hicp.en.html**).

26 '*Programme of Remediation for UK S-band (Primary) Radars*' (Information notice), Civil Aviation Authority, 24 October 2012.

estimate of the cost per filter installation, we are likely to be overestimating, as opposed to underestimating, the cost of these installations.

The total development and deployment costs for all radars in Western Europe, along with filter costs, are calculated for each year, before these costs are discounted to give a net present value for 2015, using the social discount rate of 3.5%.

3.4 Results

The results of the calculation of the total cost of relocating radars from the 2.7-2.9GHz band and also installing additional filters on radars operating in the 2.9-3.1GHz band are shown below in Figure 3-2.

Figure 3-2: Radar cost results [Source: Aetha]

Type of cost	Number of radars affected	Net present value of costs (EUR m)
Relocation of civilian ATC and bird-strike radars	124	448
Relocation of military ATC radars	49	224
Additional filters to be installed	140	47
Total costs		718

As Figure 3-2 shows, the total cost is EUR718 million, with the majority (62%) of the costs being for the relocation of civilian ATC and bird-strike radars from the band. EUR156 million of this cost (22%) is from the development costs of new radar technologies.

Note that these results are intended as an initial estimation of the costs. A more detailed assessment could be carried out in order to provide more accurate values. However, we would not expect the actual total costs of relocating the radars and installing filters to vary significantly from those presented above, as displayed by the results of sensitivity analysis discussed in the following section.

3.5 Sensitivity analysis

In this section we present the details of sensitivity analysis that we have performed on key assumptions and parameters of the calculation of the cost of relocating radars in Western Europe from the 2.7-2.9GHz band and installing filters on radars operating in the 2.9-3.1GHz band. The sensitivities discussed are regarding:

- the calculation of the number of military radars in Western Europe
- the calculation of the number of mobile bird-strike radars in Western Europe
- whether military radars operating in the 2.7-2.9GHz band can be retuned to operate in the 2.9-3.1GHz band, instead of relocating to an alternative band
- whether meteorological radars are relocated to an alternative band.

3.5.1 Calculation of military radar numbers

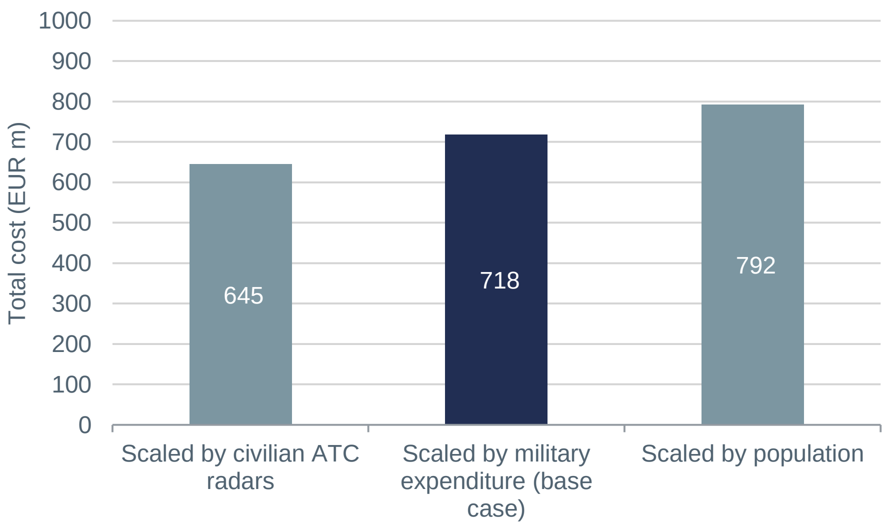
In order to estimate the number of military radars in Western Europe, we used data on the number of military radars in the UK operating in the 2.7-3.1GHz band. We estimated that 30% of these radars are operating in the lower half of this range, and then scaled up to Western Europe using data on military expenditure. This scaled the number of UK military radars up by a factor of approximately 4.6.

If instead the number of military radars in Western Europe was estimated by scaling the UK military radar numbers with the population of Western Europe, this factor would be approximately 6.5. This would lead to higher costs of relocation due to higher radar numbers. Alternatively the scaling could be done on the basis of the number of civilian ATC radars in the UK and in Western Europe. In this case the number of military radars is scaled up by a factor of approximately 2.7, which decreases the total cost of relocation.

We have assumed that the military radars operating in the frequency range 2.9-3.1GHz require additional filters, to mitigate interference from mobile services that would be operating in the 2.7-2.9GHz band. The number of these has been scaled up from the UK number using military expenditure, as for the 2.7-2.9GHz band. Scaling instead by population or civilian ATC radars leads to the same scaling factors as above, and hence leads to an increase or decrease, respectively, in numbers and hence costs of installations of filters.

The effect that these alternate ways of scaling the number of military radars has on the calculated total costs of relocating radars from the 2.9-3.1GHz band and installing additional filters to radars in the 2.9-3.1GHz band is shown below in Figure 3-3.

Figure 3-3: Sensitivity on scaling method for military radar numbers [Source: Aetha]



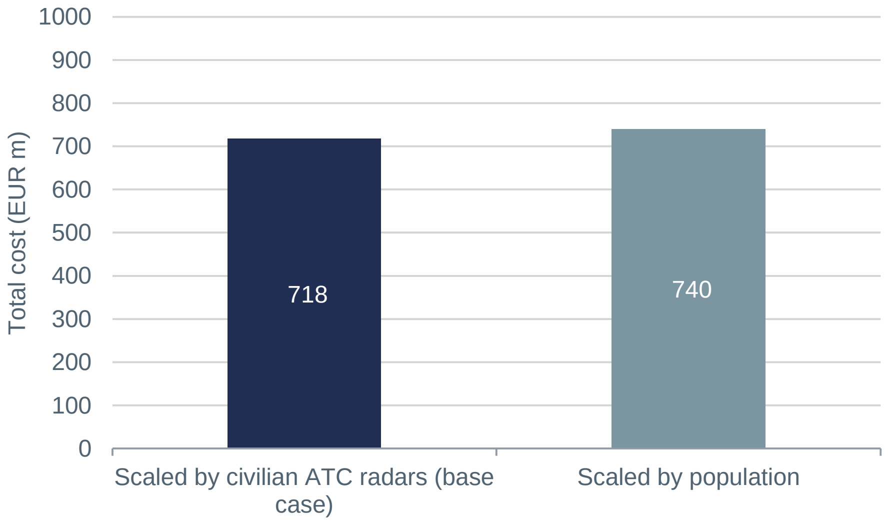
As shown in Figure 3-3, the scaling does not affect the result significantly, with a range of EUR146 million (20% of the base case). This is due to the deployment (for relocation) and filtering costs of military radars being only a small proportion of the total costs (26% in the base case).

3.5.2 Calculation of bird-strike radar numbers

Similarly to the sensitivity on the method of scaling military radar numbers to Western Europe from UK numbers (as discussed above in Section 3.5.2), we have performed sensitivity analysis on the scaling method used for bird-strike radars.

In the base case, we scaled the number of bird-strike radars in the UK up to Western Europe using civilian ATC radar numbers. In Figure 3-4, below, we show the result of instead scaling with population.

Figure 3-4: Sensitivity on the scaling method for bird-strike radar numbers [Source: Aetha]



As shown in Figure 3-4, there is a small increase in costs (EUR22 million) if scaling by population, which reflects the fact that there are relatively few bird-strike radars (only two in the UK).

3.5.3 Retuning military radars operating to the 2.9-3.1GHz band

As discussed in Section 3.1, it may be possible to retune military radars operating in the 2.7-2.9GHz band to operate in the 2.9-3.1GHz band. This would save the costs of developing and deploying a new technology to relocate these radars from the band. Instead there would be the cost of retuning these radars and installing additional filters on them, to prevent interference from the mobile services that would be utilising the 2.7-2.9GHz band. In addition, it may be necessary to re-plan the 2.9-3.1GHz band in order to free enough spectrum for these radars to occupy.

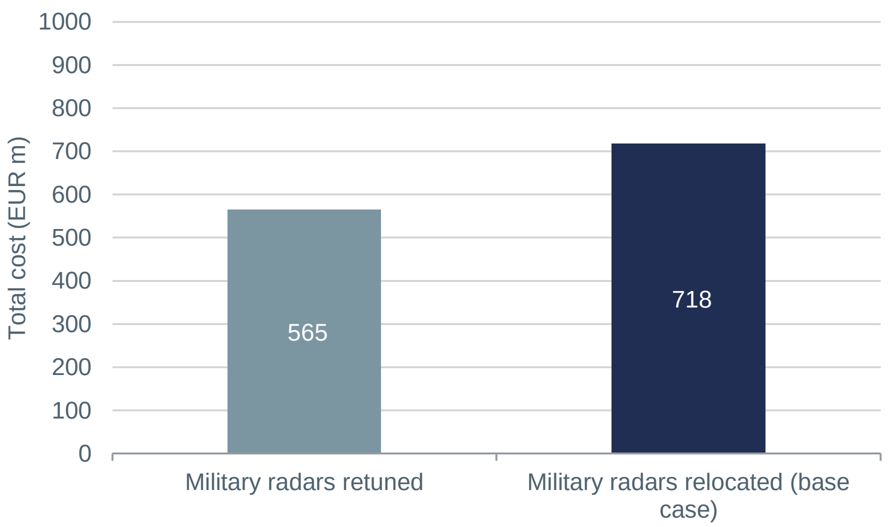
We have performed a sensitivity where this option is taken. We assume that all military radars in the frequency range 2.7-3.1GHz band need to be retuned. For simplicity, we have assumed the retuning costs per radar to be the same as the cost per radar of installing an additional filter, i.e. EUR360 000. This leads to the costs shown below in Figure 3-5.

Figure 3-5: Results in the case military radars can be retuned to the 2.9-3.1GHz band [Source: Aetha]

Type of cost	Number of radars affected	Cost (EUR m)
Relocation of civilian ATC and bird-strike radars	124	448
Additional filters to be installed	189	63
Retuning costs	163	54
Total costs		565

A comparison of the total costs between this option and the base case (where military radars are relocated from the band) is shown below in Figure 3-6.

Figure 3-6: Sensitivity on the option of retuning military radars [Source: Aetha]



As shown in Figure 3-6, retuning the military radars currently operating in the 2.7-2.9GHz band to operate in the 2.9-3.1GHz band, rather than relocating these radars to an alternative band, reduces the total cost to radar services of making the band available to mobile services by EUR153 million (21% of the base case).

3.5.4 Relocating meteorological radar to an alternative band

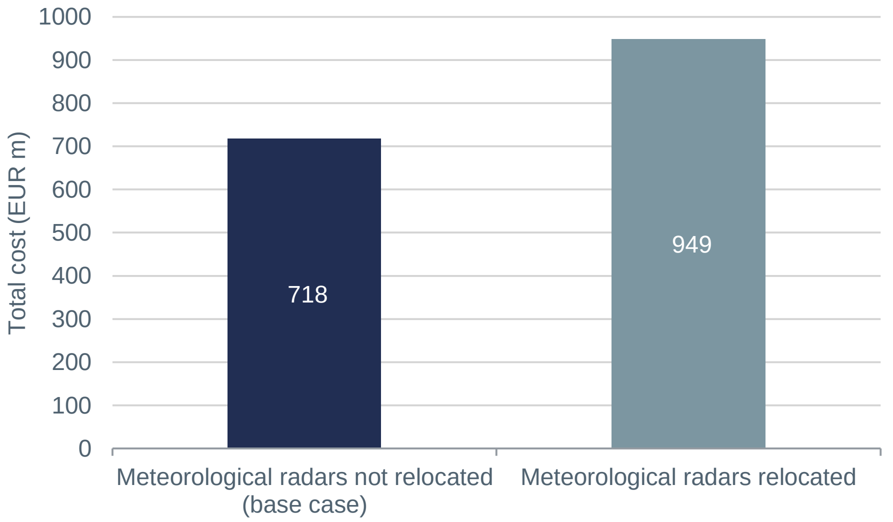
As mentioned in Section 3.1, there are a small number of meteorological radars operating in the 2.7-2.9GHz band in Western Europe (11 in total). We have not included any cost related to these radars in our estimation of the cost of relocating radars from the band. We have performed a sensitivity in order to estimate the cost if the meteorological radars were to be relocated from the band to alternative frequencies.

We assume that the cost of relocating an existing meteorological radar operating in the 2.7-2.9GHz range to another band would cost EUR1 million, with the cost incurred in 2019 or 2020. We assume that these radars would be relocated to a higher frequency band and that the poorer propagation in this band would mean that new radar sites would need to be deployed. We assume that a total of four times the number of existing meteorological radars currently operating in the 2.7-2.9GHz band would be required to compensate for this lower coverage per radar (i.e. 44 meteorological radars in total in Western Europe, including the existing radars). We have estimated that the deployment of radars on new sites would cost around EUR5 million per site. Half of these costs have been increased with inflation, to reflect the assumed labour component of installation.

In addition to the deployment costs of new radar sites, we have assumed that operational staff would be required on each new site. We assume that three members of staff would be required per site and a total employment cost of EUR50 000 per member of staff per year, rising with inflation.

The estimated cost of relocating the existing meteorological radars to an alternative spectrum band and the cost of new sites are added to the costs of relocating civilian and military radars from the band and installing additional filters to radars operating in the 2.9-3.1GHz band to estimate the total cost involved for radar, should the 2.7-2.9GHz band be made available to mobile services. The result is shown below in Figure 3-7.

Figure 3-7: Sensitivity on the additional relocation of meteorological radars [Source: Aetha]



As shown in Figure 3-7, the cost of relocating these radars raises the total costs by EUR231 million (32% of the costs in the base case). Of this cost EUR11 million (5%) is from relocating the existing radars, with the remainder (EUR220 million) being the costs associated with the new radar sites, EUR69 million of which relates to the additional staff costs.

4 Economic benefits from use of the band for mobile broadband

In this section we discuss the approach to and findings of the assessment of the economic benefits for mobile broadband services if the 2.7-2.9GHz band is made available to mobile network operators. We start with some background on the use of spectrum bands for mobile services in Western Europe. Then we discuss in detail the approach to calculating the total benefit of the band to mobile broadband services. Finally in this section we present our findings on the benefits involved and also present sensitivity analysis on some key assumptions.

4.1 Background

In the last few years, mobile operators in Europe have begun to utilise Long Term Evolution (LTE) mobile technology. This provides operators with the ability to offer faster mobile broadband services to subscribers. This is becoming increasingly important, as data usage continues to grow at a significant rate. This traffic is forecast to grow further in the coming years and network operators will need to react to this.

A MNO will typically have base stations deployed to provide coverage to the majority of the population of the country they operate in. In areas with high traffic levels these base stations may not be able to meet demand. In this case, there are two options available to the network operator in order to increase capacity:

- additional sites can be built
- additional spectrum bands can be deployed on the relevant existing sites.

The amount of spectrum (MHz) that is deployed on a site is approximately proportionate to the amount of traffic that the site can carry (over a specific time period). The addition of spectrum bands to sites is typically considerably less expensive than building and maintaining additional sites. Thus the availability of new spectrum bands for mobile LTE services can save operators considerable amounts of money and is therefore a key part of the solution to coping with the huge growth in traffic expected.

At WRC-15 additional spectrum bands are expected to be announced as having mobile services as their primary allocation in Europe. This includes bands such as the 700MHz band, currently occupied by digital terrestrial television in many countries. The 2.7-2.9GHz band provides an attractive potential candidate band as it is currently underused (by radars) in many countries and is also adjacent to the 2.6GHz band, which is widely used for mobile services in Europe.

4.2 Methodology for calculating economic benefits to mobile services

As discussed briefly in Section 2.1.2, the economic benefits of the band to mobile services are assessed by calculating the network savings that a MNO in a theoretical Western European Market would have, and then converting this from producer surplus to consumer surplus. These steps are discussed in detail in this section, along with the key assumptions involved.

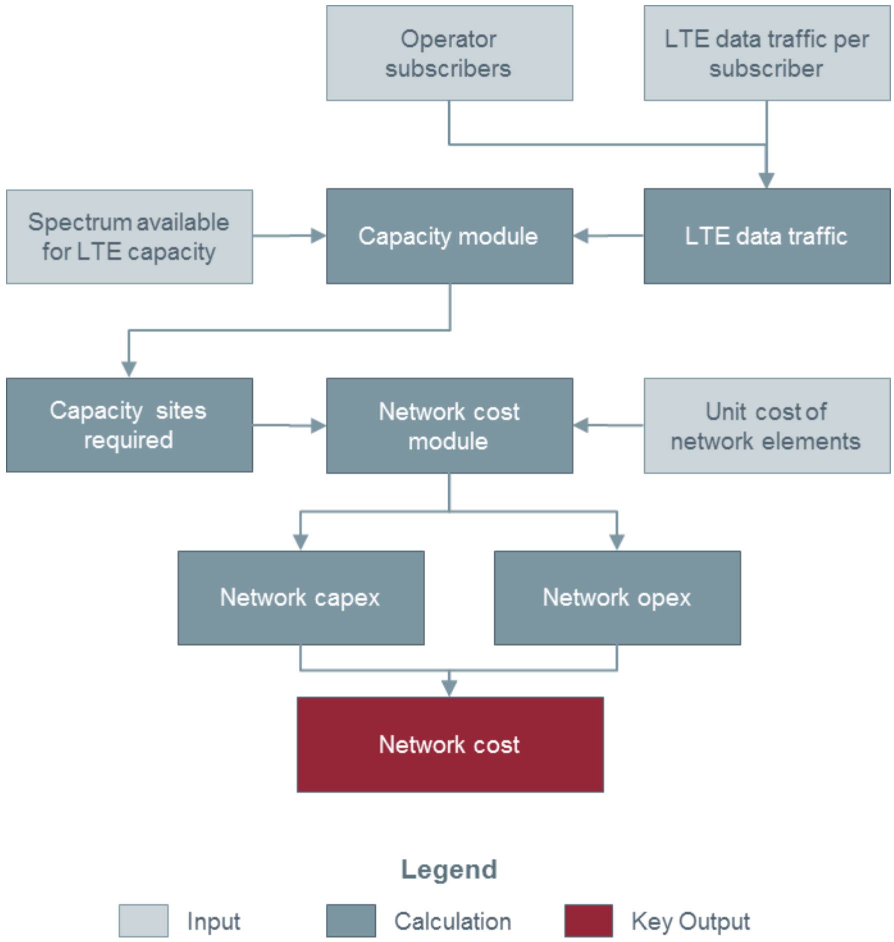
4.2.1 Approach to calculating the network savings of a MNO in a theoretical market

We have calculated the network cost savings of a MNO in a theoretical Western European country, which we assume has the following characteristics, based on knowledge of various Western European markets:

- a steady population of 50 million
- 3 MNOs in the country, each with equal market share
- each operator has a current site grid of 10,000 sites, in order to provide sufficient coverage and carry current traffic levels.

To calculate the network cost savings for this theoretical MNO we consider the difference between the network costs of the company in the scenarios with and without the 2.7-2.9GHz band available for mobile services. This involves calculating the number of additional capacity sites required to carry the traffic of the theoretical operator in each scenario, and calculating the costs these sites would incur. An overview of the network cost calculation is shown in Figure 4-1, and discussed in detail below. These costs are calculated for each year of the modelling period, from 2010 to 2035, although there will be no difference between the scenarios with and without the 2.7-2.9GHz band available for mobile services until the band would be introduced in 2021, once radar services have been relocated from the band.

Figure 4-1: Calculation flow of network capacity costs [Source: Aetha]



Combining the population of the theoretical country with the operator's market share and a forecast of mobile SIM penetration gives the number of subscribers (i.e. the number of active SIMs) that the operator has each year. We have assumed that mobile penetration in Western Europe increases from 128% in 2011[27], to 170% by 2025, remaining constant thereafter.

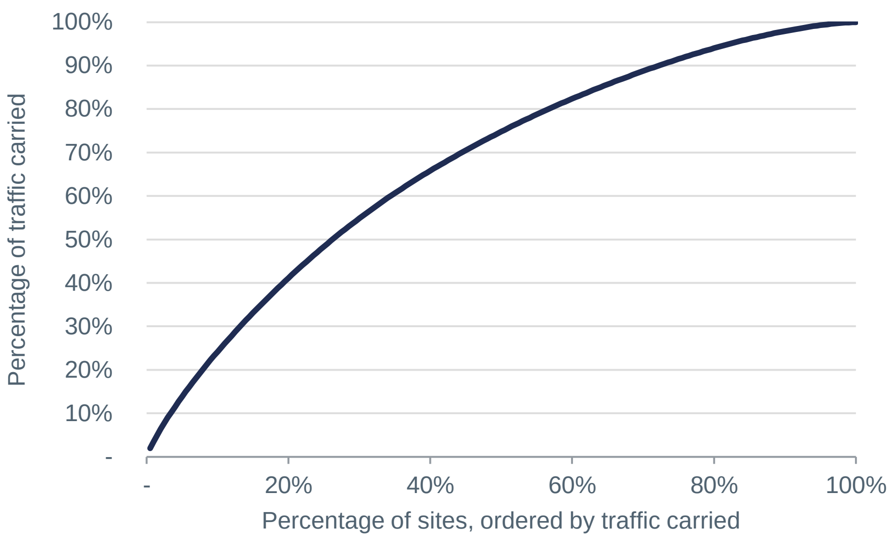
[27] '*European Mobile Industry Observatory 2011*', GSM Association, November 2011.

Subscriber numbers together with a forecast of LTE traffic per subscriber gives the total traffic the theoretical operator should carry on its network. The traffic forecast is discussed in detail below in Section 4.2.2. The operator's traffic is then scaled to represent the downlink traffic in the busiest hour of the day on the busiest sector of each site, as this is the traffic that will constrain the operator and hence the traffic that the operator will dimension their network based on. We have assumed the following percentages for these parameters, based on knowledge of the network measurements of various operators:

- 80% of traffic is assumed to be downlink traffic
- 10% of the daily traffic is assumed to occur in the busiest hour of the day
- 55% of a site's traffic is assumed to occur in the busiest sector of the site.

The traffic is distributed amongst the operator's sites by splitting the sites into 200 groups, with similar traffic levels within each group. The distribution used is shown below in Figure 4-2 and is based on knowledge of the traffic distribution on sites of various relevant operators.

Figure 4-2: Distribution of traffic over operator sites [Source: Aetha]



The spectrum available to the operator for LTE capacity use is a key input to the capacity calculation, as it determines how much traffic each site can carry. The addition of the 2.7-2.9GHz band for mobile services from 2021, once radar has left the band, would allow the theoretical operator to carry more traffic on each site. The assumptions on available spectrum are detailed below in Section 4.2.3. Also, the capacity of each sector on a site per MHz of spectrum will increase as the LTE technology is improved and used more efficiently. The assumptions on sector capacity are discussed in Section 4.2.4.

The traffic, available spectrum and sector capacity inputs feed into the capacity module, which calculates how many sites and carriers are required to hold the traffic. It is assumed that the operator deploys every band other than the 2.7-2.9GHz band on each new site and deploys the 2.7-2.9GHz band (in the scenario with the band available for mobile services) separately in order to avoid the cost of new sites.

The cost of operating and building the sites is then calculated using forecasts for unit costs. These are based on a benchmark of operators' current costs and forecasts and the details are displayed below in Figure 4-3.

Figure 4-3: Unit cost capex and opex assumptions [Source: Aetha]

Network cost element	Unit cost in 2013 (EUR)	Year-on-year price trend
New site	185 000	1.5%
New frequency band on existing site - Antennas	2000	-2%
New frequency band on existing site – Other equipment	25 000	-2%
Site opex (per year per site)	13 000	2%
Additional site opex for 2.7-2.9GHz band (per year per site)	250	2%
Backhaul capex (per site)	8000	-1%
Backhaul opex (per year per site)	2000	-

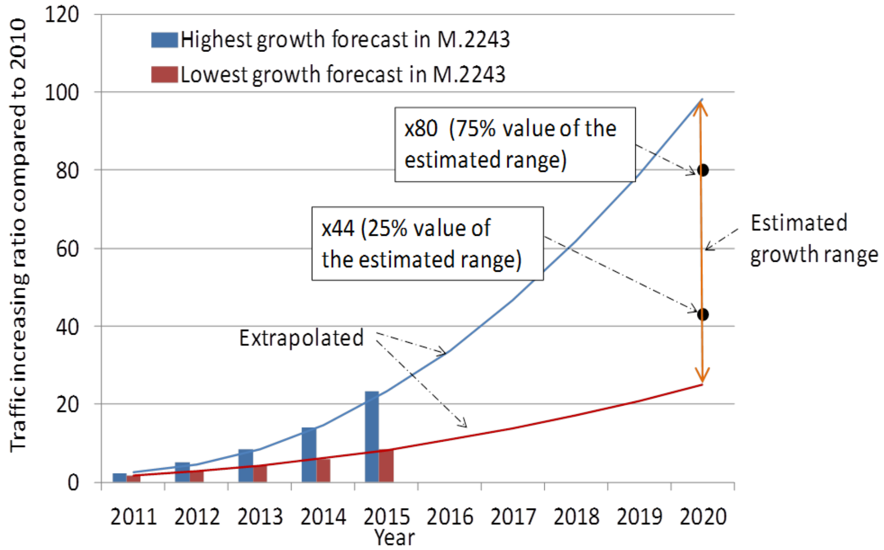
The calculation of network costs is performed in the scenario with and the scenario without the 2.7-2.9GHz band available for mobile services, and the difference taken for each year to give the network cost savings for the operator for each year from having use of the 2.7-2.9GHz band.

4.2.2 Traffic forecast

The traffic forecast is a key driver in the model as it drives the need for the theoretical operator to build additional sites and upgrade existing sites. We have based our forecast on two recent studies:

- An ITU publication[28] provides lower and upper bounds for future traffic, until 2020, compared to 2010 levels. It predicts traffic in 2020 to be between about 26 and 98 times the traffic in 2010. This forecast is shown below in Figure 4-4.
- A UMTS Forum report[29] forecasts total global traffic until 2025 and traffic in a representative Western European country with population 50 million until 2020, as shown below in Figure 4-5.

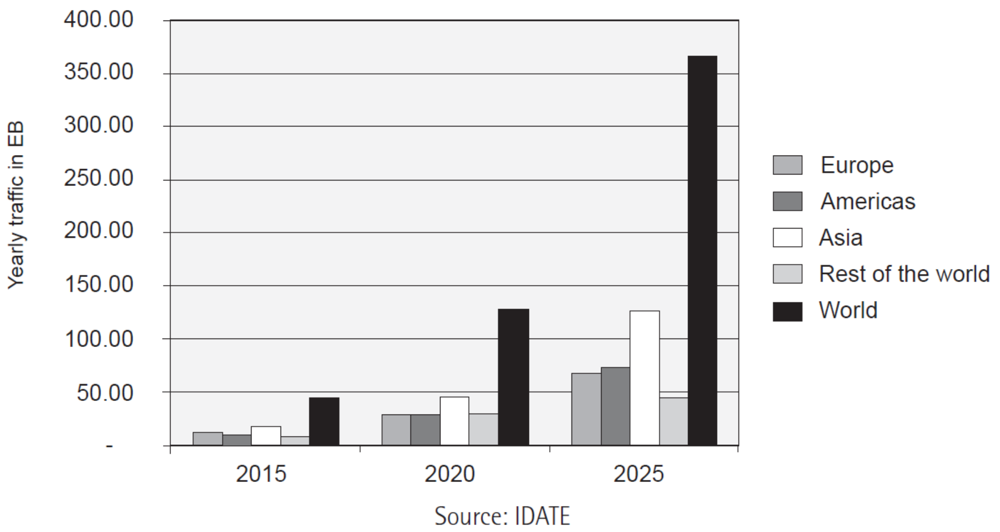
Figure 4-4: Mobile traffic forecasts towards 2020 by extrapolation [Source: ITU[28]]



[28] '*Meeting Report of SWG IMT.TRAFFIC at WP 5D #15*', ITU, 5 February 2013.

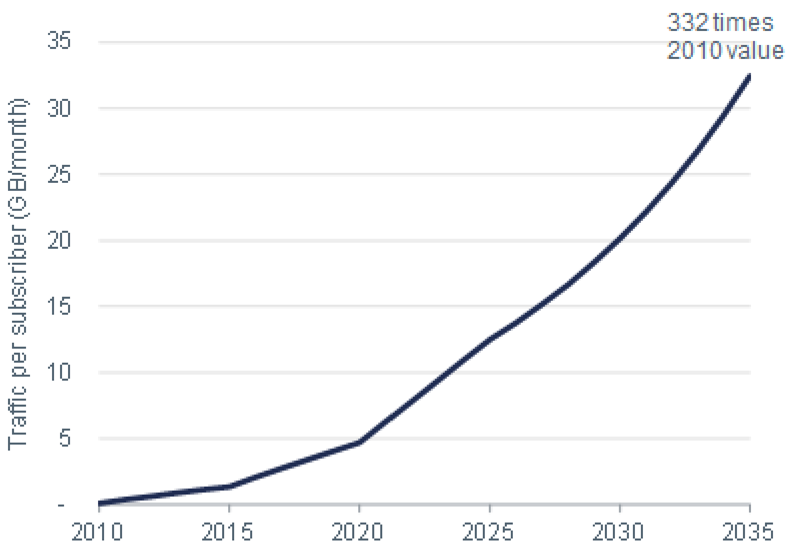
[29] '*Mobile traffic forecasts 2010-2020 report*', UMTS Forum, January 2011.

Figure 4-5: 2025 mobile traffic forecasts [Source: UMTS[29] (IDATE)]



To derive the forecast used in our model we start with the 2010 traffic as stated for the representative Western European country in the UMTS Forum report. We then apply a trend of the average of the upper and lower bounds from the ITU publication, until 2020. We then apply the global trend forecast from 2020 to 2025 in the UMTS Forum report to derive a forecast for 2025. After 2025 we assume a year-on-year increase of 10%, in line with the trend up to 2025. The resulting forecast per SIM (including voice-only SIMs) is displayed below in Figure 4-6.

Figure 4-6: Traffic forecast per SIM for theoretical Western European operator [Source: Aetha, based on forecasts from the ITU and UMTS Forum]



As this forecast is a key assumption, sensitivity analysis has been performed and is discussed in Section 4.4.2.

4.2.3 Spectrum bands available to mobile operators

The capacity of sectors on a MNO's sites is directly related to the amount of spectrum deployed on the site. The exact relationship is discussed below in Section 4.2.4. Effectively, the more spectrum an operator deploys on its sites, the higher the capacity of these sites and the fewer new sites need to be built. Therefore, the amount of spectrum available to the theoretical operator is a key assumption. We have included the current harmonised bands used for mobile services in Europe, along with bands which are likely to be available to operators in the near future. We assume that these bands are available for LTE use by the time the 2.7-2.9GHz band would become available for use in 2021, once the radars have been relocated from the band.

We assume that as the operator has a third of the market share in the theoretical country, it also owns about a third of the spectrum. LTE is typically deployed in 5MHz (or 2×5MHz in the case of paired FDD spectrum) blocks and is mostly made available to operators in this form. We therefore assume that the operator has approximately one third of these blocks in each band, as opposed to exactly one third of the spectrum. The bands we have assumed are available to the operator, along with the amount of spectrum available to the operator are shown below in Figure 4-7.

Figure 4-7: Spectrum available to theoretical operator [Source: Aetha]

Band	Total spectrum available for mobile (MHz)	Spectrum assigned to operator (MHz)	Percentage of MHz taken by operator
450MHz (TDD)	20	5	25%
700MHz (FDD)	60	20	33%
800MHz (FDD)	60	20	33%
900MHz (FDD)	70	20	29%
1400MHz (FDD downlink only)	40	15	38%
1800MHz (FDD)	150	50	33%
2.1GHz (FDD)	120	40	33%
2.3GHz (TDD)	100	35	35%
2.6GHz (FDD)	140	40	29%
2.6GHz (TDD)	45	15	33%
Total (exc. 2.7-2.9GHz)	805	260	32%
2.7-2.9GHz (FDD)	180	60	33%
Total (inc. 2.7-2.9GHz)	985	320	32%

As can be seen in Figure 4-7, in the scenario with the 2.7-2.9GHz band available for mobile services the theoretical operator would have an additional 60MHz (2×30MHz) of FDD spectrum from the band[30]. We have assumed that 180MHz of the band would be available for mobile use in total, from the 200MHz in the band, since there will likely be a need for guard bands at the top and bottom of the bands (in particular at the top of the band in order to prevent interference to and from radars operating above the band) and there will be a duplex gap between the uplink and downlink parts of the band.

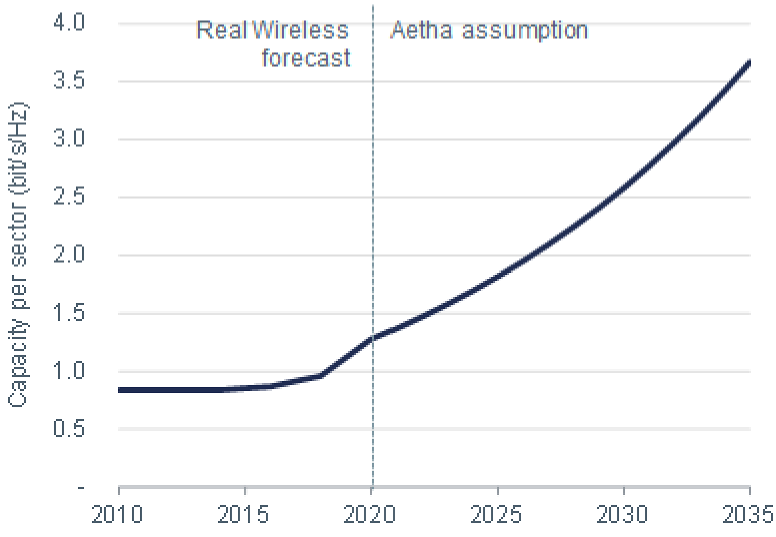
Another band that has not been included, but could potentially be available to the operator is the 3.5GHz band. This would give mobile operators an additional 200MHz of TDD spectrum. However, as the 2.7-2.9GHz band has better propagation properties (due to the lower frequencies) and is also adjacent to the 2.6GHz band, potentially leading to better equipment availability, it is unlikely that the 3.5GHz band would be used in preference. Hence this band has been included as a sensitivity as discussed in Section 4.4.1.

30 Note that the results would not change if we assumed the band was available instead as TDD spectrum, since we use the same capacity per MHz for TDD as FDD.

4.2.4 Sector capacity assumptions

The spectral efficiency of an LTE carrier determines how much traffic within a sector can be carried over the bandwidth of the carrier. Improvements in technology and utilisation lead to improved spectral efficiency. A Real Wireless study for Ofcom into LTE capacity gains[31] includes a forecast of spectral efficiency for LTE until 2020. We have utilised this forecast and extended it using the CAGR from 2014 to 2020 to give a year-on-year trend of approximately 7% thereafter. The forecast used is shown below in Figure 4-8.

Figure 4-8: Spectral efficiency of LTE [Source: Real Wireless, Aetha]



We assume that TDD spectrum has the same capacity per MHz as FDD spectrum.

It is likely that the spectral efficiency of LTE will stop rising at such an increasing rate at some point in the future, and this could potentially occur before the end of the modelling period. As such we have assessed the impact of a lower long-term spectral efficiency as a sensitivity to the main model results, as discussed in Section 4.4.3.

4.2.5 Passing the cost savings to consumers

In Section 4.2.1 we provided details for the calculation of the network cost savings of a theoretical Western European operator. In a competitive market these cost savings would be passed on to the consumer in the form of lower prices (or equivalently, better bundles), in order for the operator to retain its position in the market. The model calculates the consumer surplus once the savings have been passed on, in the scenarios with and without the 2.7-2.9GHz band available for mobile services. These are calculated for the whole theoretical market and then scaled up to Western Europe by population. The difference between the two is then the total economic benefit of the band to mobile broadband services in Western Europe.

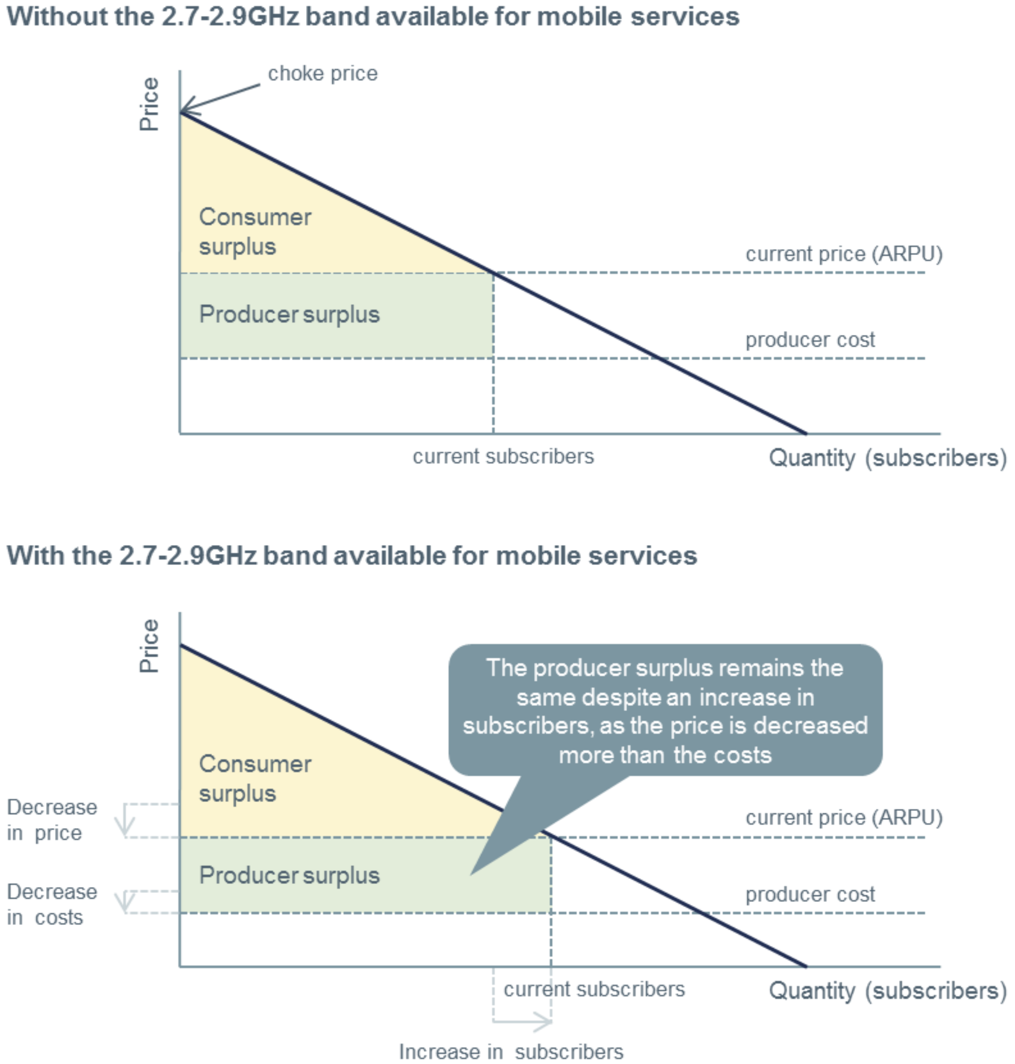
The network cost savings, corresponding to an increase in producer surplus before any price reduction, are calculated for each year. The model converts these savings into consumer surplus, such that the producer surplus is the same in the scenario with and the scenario without the 2.7-2.9GHz band available for mobile

[31] '*Report for Ofcom: 4G Capacity Gains*', Real Wireless, 27 January 2011.

services. That is, the producers, i.e. the MNOs, make the same profit each year regardless of the availability of the 2.7-2.9GHz band.

As the MNOs lower their prices, this attracts more subscribers. Hence operators are able to drop their prices by more than their cost savings in the scenario with the 2.7-2.9GHz band available for mobile services. This is illustrated in Figure 4-9 below. Note that the model calculates a separate linear demand curve for each year, which is used in both scenarios.

Figure 4-9: Producer and consumer surplus in the scenarios with and without the 2.7-2.9GHz band available for mobile services
[Source: Aetha]



In order to define the demand curves, we have forecast ARPU levels for Western Europe in the scenario with 2.7-2.9GHz band available for mobile services. The 2011 ARPU (approximately EUR 21 per month per subscriber) is based on data from a Merrill Lynch study[32]. We have forecast a 1% decrease each year until 2015, in line with current trends. These trends have mainly been due to decreases in mobile termination rates, which are now levelling out. Between 2015 and 2020 we keep ARPUs constant before

32 '*Global Wireless Matrix 3Q11*', Merrill Lynch, 28 September 2011.

increasing by 1% each year thereafter, due to an expected upturn in the economic situation of Western Europe.

The demand curve for 2013 is derived from the ARPU forecast and subscriber numbers for the theoretical market, along with a price elasticity of demand. The price elasticity is a measure of how the subscriber numbers would react to a change in the price of the service. It is the percentage change in the number of subscribers resulting from a 1 per cent change in price. Estimates of the price elasticity for mobile services vary considerably within academic literature. Therefore, we have used a ‘symbolic average’ of estimates from a variety of studies of -0.55, as is suggested by a recent survey of Benzoni & Deffains[33].

The survey considers values from an earlier study by Grzybowski[34], which derives elasticities for each of the EU15 countries (each of which belongs to our definition of Western Europe). The most recent estimates of this study are smaller than -0.55, however a study on the elasticity in Austria[35] claims that the value could be as low as -1.1, whilst a more recent study[36] estimates elasticity for European countries to be in the range -0.52 to -0.61. As there is a wide range of estimates of the price elasticity we have included some sensitivity analysis on this input in Section 4.4.4.

From the demand curve for 2013 we have inferred a choke price, i.e. the minimum price at which there would be no subscribers (as shown in Figure 4-9 for the scenario with the 2.7-2.9GHz band available for mobile services). Demand curves for the years following 2013 are then based on a forecast trend of the choke price. We have assumed that the choke price follows the same trend as the ARPU, but with an additional decrease of 1% each year, to reflect the decreasing value of the service as it increases in age.

To calculate producer surplus in the scenario without the 2.7-2.9GHz band available for mobile services (and hence also in the scenario with the band available for mobile services, as the producer surplus is set to be equal in both scenarios), we assume that the producer costs are 50% of the producer revenues, based on the current financial situation of various operators. In the scenario with the 2.7-2.9GHz band available for mobile services these costs are lowered by the network cost savings per subscriber from the availability of the band. We have assumed that an increase in subscribers does not affect the producer cost per subscriber (i.e. overall producer costs are proportional to the number of subscribers).

In the scenario without the 2.7-2.9GHz band available for mobile services the consumer surplus is then calculated for each year, from the demand curves, subscriber numbers and ARPU forecasts. In the scenario with the 2.7-2.9GHz band available for mobile services, with the producer surplus fixed and producer costs calculated, the demand curves then define both the current subscriber numbers and ARPU for each year. From this the consumer surplus is calculated.

The consumer surplus for each scenario is then discounted to give a net present value for 2015, using the social discount rate of 3.5%. These are scaled up to Western Europe by population. The difference between the net present values for the scenarios with and without the 2.7-2.9GHz band available for mobile is then

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33 ‘*Market Homogenisation or Regulation Harmonisation? The Welfare Cost of a European Mobile Market without the Later Entrant Operators*’, L. Benzoni & B. Deffains, 2012.

34 ‘*The Competitiveness of Mobile Telephony across the European Union*’, L. Grzybowski, 2008.

35 ‘*Demand Elasticities for Mobile Telecommunications in Austria, Journal of Economics and Statistics*’, R. Dewenter & J. Haucap, 2008.

36 ‘*The Effects of Lower Mobile Termination Rates (MTRs) on Retail Price and Demand*’, C. Growitsch, J. S. Marcus & C. Wernick, 2010.

taken, in order to arrive at the total benefit of the 2.7-2.9GHz band to mobile broadband services in Western Europe.

As a sensitivity, we have also calculated the benefit of the band to mobile services if operators were not to pass their network cost savings on to consumers. This is discussed in Section 4.4.5.

4.3 Results

The benefit to mobile broadband services in Western Europe of being able to use the 2.7-2.9GHz band from 2021 is calculated on the basis of the network cost savings of a mobile network operator in a theoretical Western European market. This network cost saving is due to the operator building and maintaining fewer sites in the scenario when the operator has access to spectrum in the 2.7-2.9GHz band. The estimated number of additional sites built by the theoretical operator in the scenarios with and without the 2.7-2.9GHz band available for mobile services are summarised in Figure 4-10 below.

Figure 4-10: Additional site build of the theoretical Western European operator [Source: Aetha]

Scenario	Number of sites built by the theoretical operator by 2035
Without the 2.7-2.9GHz band for mobile	1650
With the 2.7-2.9GHz band for mobile	800
Sites saved if the 2.7-2.9GHz band is available to the theoretical operator	850

As Figure 4-10 shows, the theoretical operator would have to build an additional 850 base station sites by 2035, if it did not have access to the 2.7-2.9GHz band. This represents an extra 8% of the operator’s total sites being built.

The network cost savings are assumed to be passed on to consumers in the form of lower prices, leading to an increase in consumer surplus. This increase in consumer surplus scaled to Western Europe represents the overall economic benefit to mobile broadband services of the 2.7-2.9GHz band. In this study, we have estimated the economic benefits of the band to mobile services as EUR8143 million.

Note that this study is intended as an initial high-level assessment of the economic benefit of making the 2.7-2.9GHz band available to mobile services in Western Europe. Therefore, a more detailed study could improve on the accuracy of this result. In order to estimate the range of likely values for the economic benefit of the band to mobile services we have performed sensitivity analysis on some key inputs and assumptions, with the results discussed in the following section.

4.4 Sensitivity analysis

In this section we present details of the sensitivity analysis that we have performed on key assumptions and parameters of the calculation of the benefit of the 2.7-2.9GHz band to mobile broadband services in Western Europe. The sensitivities discussed are regarding:

- the availability of the 3.5GHz band
- the traffic forecast
- the forecast of the spectral efficiency of LTE
- the price elasticity of demand
- whether the network cost savings are passed on to consumers
- the time at which the 2.7-2.9GHz band becomes available.

4.4.1 Availability of the 3.5GHz band to mobile operators

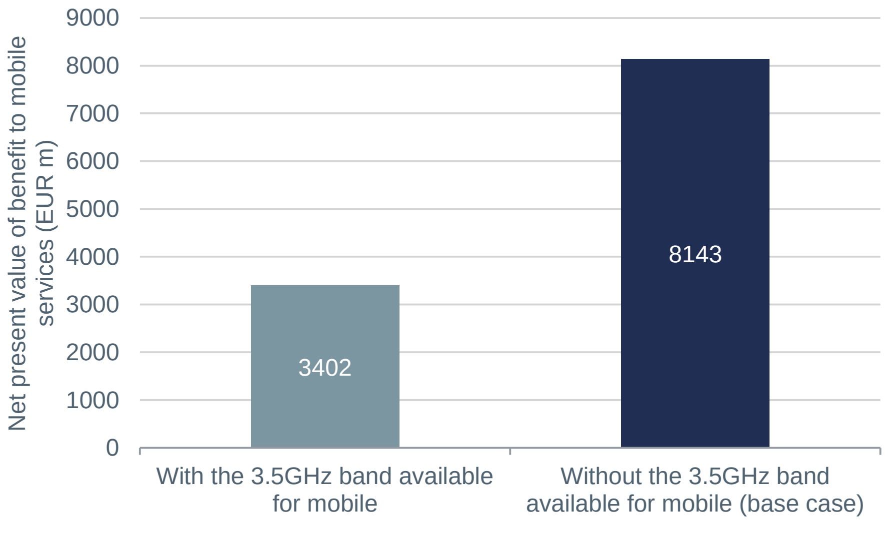
As discussed in Section 4.2.3, we have not included the availability of the 3.5GHz band for mobile services in the base case. If this band was available to MNOs by 2021 in Western Europe, and there was a preference for use of this band over the 2.7-2.9GHz band, then MNOs would value the 2.7-2.9GHz band less. With more spectrum available to them, MNOs can increase the capacity of their sites. This leads to a proportionally smaller capacity benefit of the spectrum in the 2.7-2.9GHz band, compared to the base case, and hence smaller network savings, which are converted to a smaller benefit in consumer surplus.

We model this as a sensitivity by increasing the theoretical operator's spectrum holdings by 70MHz (35% of the 200MHz of spectrum in the 3.5GHz band). We have also increased some of the network unit costs to reflect the use of this additional band:

- New sites, built for capacity, are assumed to have carriers from each band (except the 2.7-2.9GHz band) deployed. To reflect the 3.5GHz band being additionally deployed in this sensitivity, new site costs are increased by EUR10 000 (in 2013).
- To reflect the additional energy and maintenance costs from having the 3.5GHz band deployed, site opex per year is increased by EUR250 (in 2013).

The result of this sensitivity analysis is shown below in Figure 4-11.

Figure 4-11: Sensitivity on the availability of the 3.5GHz band [Source: Aetha]



As shown in Figure 4-11, there is a significant decrease in benefit to mobile services of the 2.7-2.9GHz band if the 3.5GHz band is already available. The effect is large (a 58% decrease in benefit from the base case) partly because of the size of the 3.5GHz band. Having an extra 70MHz of spectrum available means that the theoretical operator only saves building 350 new sites with the 2.7-2.9GHz band (compared to 800 in the base case).

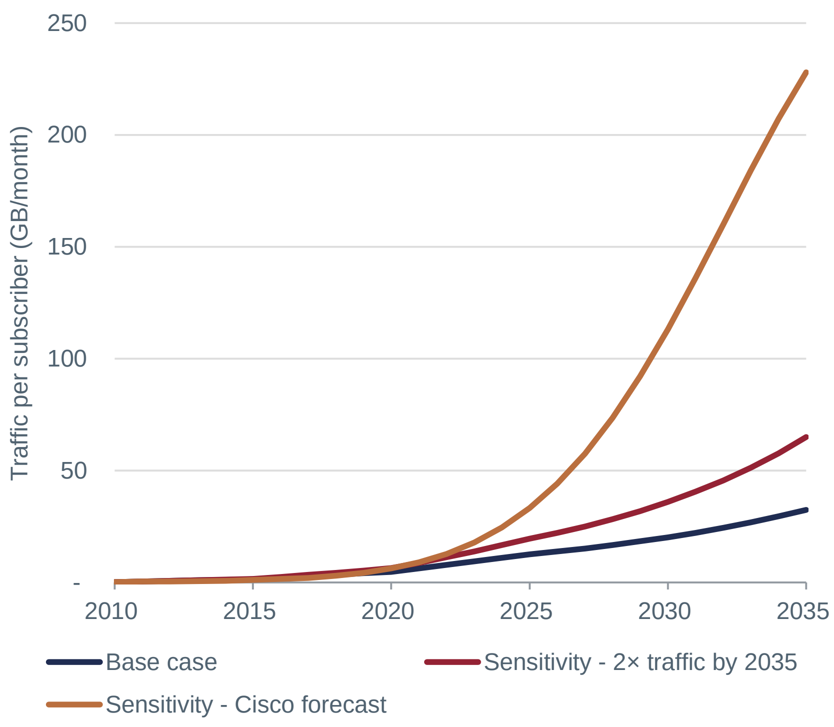
4.4.2 Alternative traffic scenarios

The traffic forecast used in the base case is derived from ITU and UMTS Forum forecasts. However, as a sensitivity we have also considered a traffic forecast based on a forecast of Cisco[37]. After the Cisco forecast

[37] '*Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012–2017*', Cisco, 6 February 2013.

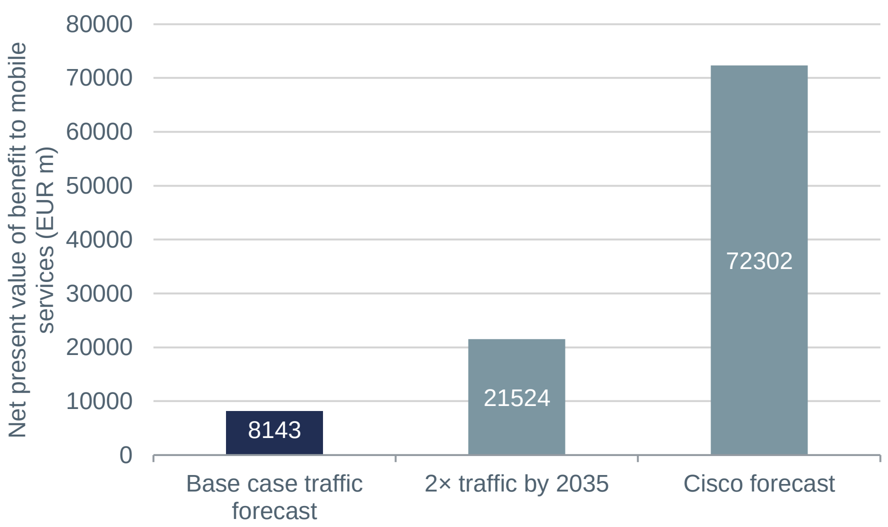
ends in 2017, we have assumed a trend based on the CAGR from 2012-2017 (approximately 48%). We reduce the year-on-year trend each year from 2020, with the traffic per subscriber being about 7 times that of our base case traffic forecast in 2035. As a further sensitivity we have considered traffic in between this forecast and the base case forecast, by considering a forecast that leads to twice as much traffic as the base case in 2035. The forecasts are shown below in Figure 4-12.

Figure 4-12: Traffic forecasts for sensitivities [Source: Aetha]



The extra traffic in each sensitivity forecast requires additional sites to be built and hence increases the benefit of the spectrum in the 2.7-2.9GHz band to mobile services. The result of this increased traffic demand on the economic benefit of the 2.7-2.9GHz band to mobile services is shown below in Figure 4-13.

Figure 4-13: Sensitivity on the traffic forecast [Source: Aetha]

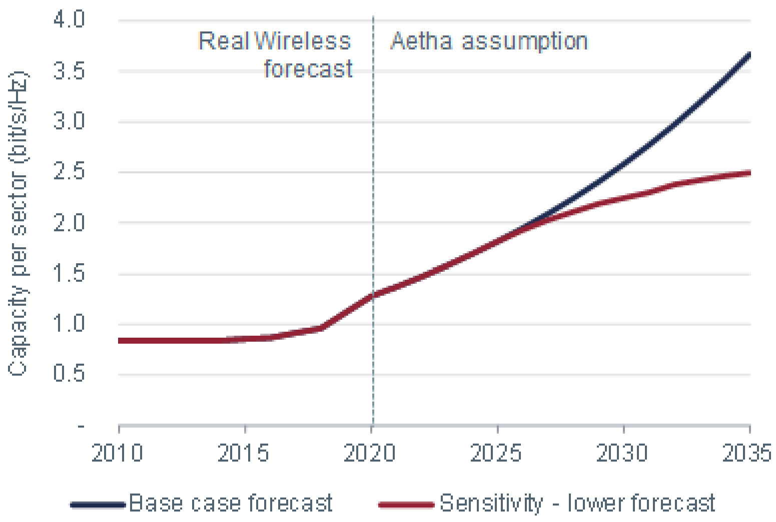


As the above figure shows, the impact of this increased traffic is very significant, with the benefit of the 2.7-2.9GHz band to mobile services increasing from EUR8143 million in the base case to EUR21 524 million with twice the traffic in 2035 and EUR72 302 million in the sensitivity based on the Cisco forecast. This represents an increase in benefit of approximately 2.6 times and 8.9 times the base case value, respectively.

4.4.3 Lower spectral efficiency gains

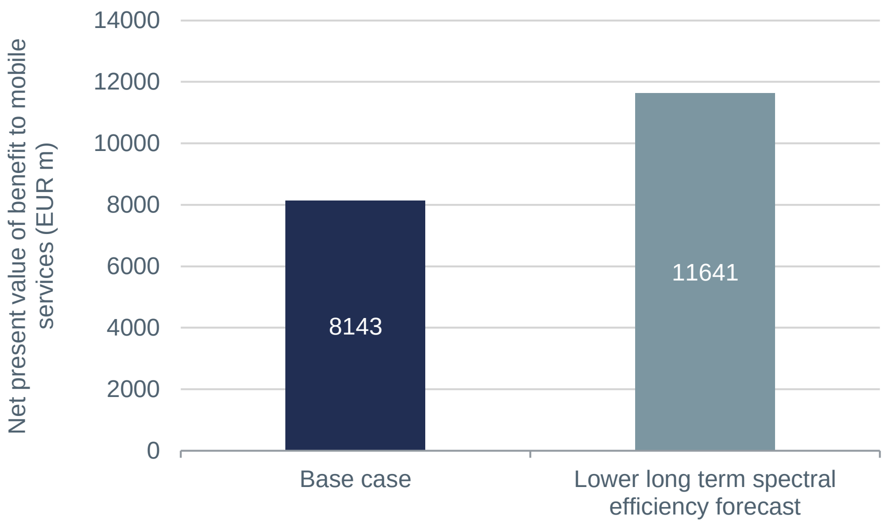
The forecast for the spectral efficiency of LTE was discussed in Section 4.2.4. This forecast consisted of a Real Wireless forecast until 2020, followed by an assumption that the year-on-year trend would continue until 2035. As a sensitivity we have considered the case that the increase slows down before 2035. This alternative forecast is shown below in

Figure 4-14: Spectral efficiency of LTE [Source: Aetha]



The lower spectral efficiency in later years of the model, compared to the base case forecast, lowers the capacity of sites on which the same amount of spectrum is deployed. This leads to the need for additional sites, which increases the benefit of the 2.7-2.9GHz spectrum. The result of the sensitivity analysis is shown in Figure 4-15 below.

Figure 4-15: Sensitivity on the spectral efficiency of LTE forecast [Source: Aetha]



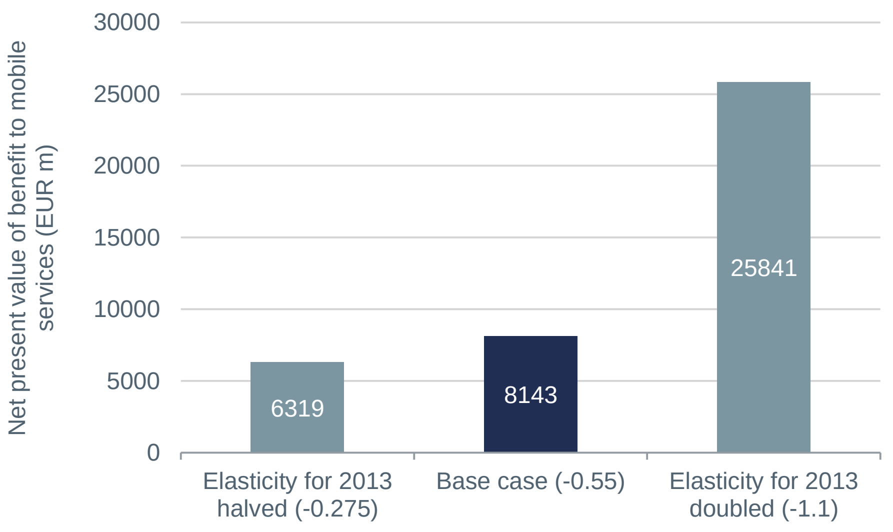
As shown in Figure 4-15, the result of using a lower long term spectral efficiency forecast is that the estimate of the benefits of the 2.7-2.9GHz band rise from EUR8143 million to EUR11 641 million.

4.4.4 Price elasticity of demand

As discussed in Section 4.2.5, estimates of the price elasticity of demand for mobile services vary significantly between studies. The elasticity is used to derive the demand curves and hence affects the conversion of producer surplus into consumer surplus. A higher, less negative, elasticity implies a steeper, more negative, gradient for the demand curves. This translates into a smaller increase in subscribers when prices are reduced in the scenario with the 2.7-2.9GHz band available for mobile services, leading to a smaller increase in consumer surplus.

We have performed a sensitivity on the elasticity of demand, both doubling and halving the base case value of -0.55. This covers the range of elasticities stated in the publications discussed in Section 4.2.5. The results of this sensitivity analysis are shown below in Figure 4-16.

Figure 4-16: Sensitivity on the price elasticity of demand [Source: Aetha]

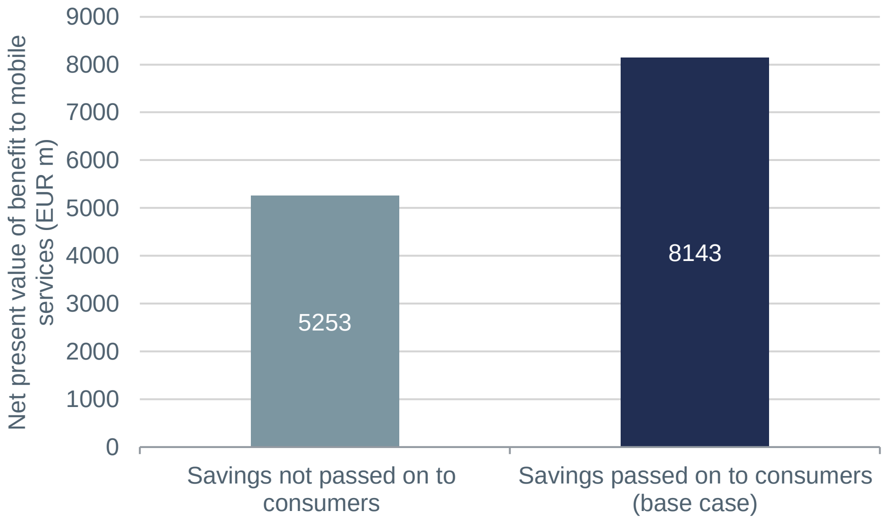


As shown above in Figure 4-16, halving the price elasticity of demand for 2013 decreases the estimate of the benefit of the 2.7-2.9GHz band to mobile services from EUR8143 million to EUR6319 million. Doubling the elasticity has a more significant impact, increasing the benefits to EUR25 841 million.

4.4.5 Savings not passed on to consumers

As a sensitivity we consider the benefit of the 2.7-2.9GHz band if the network cost savings to MNOs are not passed on to consumers through lower prices. That is, we consider the increase in producer surplus due to the network cost savings, before it is converted to an increase in consumer surplus. The result is shown in Figure 4-17 below.

Figure 4-17: Sensitivity on the conversion of producer surplus to consumer surplus [Source: Aetha]



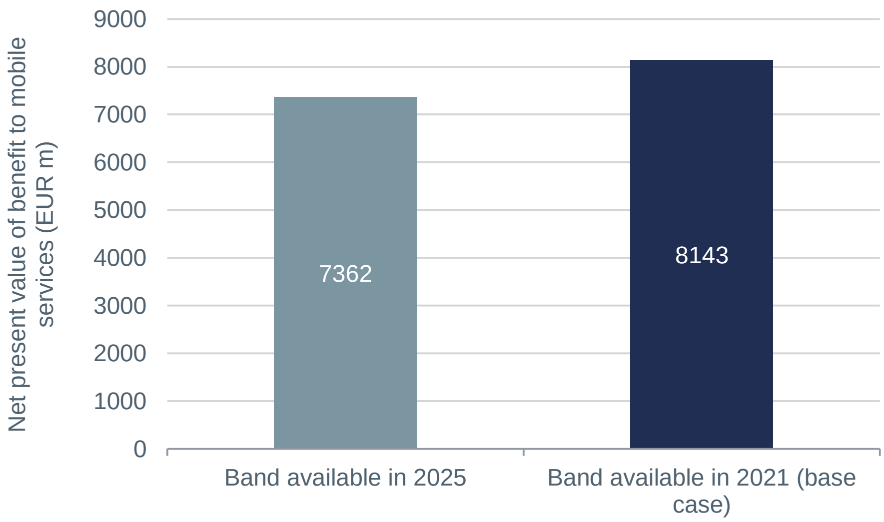
As the above figure shows, the conversion of producer surplus to consumer surplus has increased the economic benefits of the 2.7-2.9GHz band to mobile from EUR5253 million to EUR8143 million. This is a multiplier effect of about 1.6 (an extra 60% of benefit).

4.4.6 Timing of availability of the 2.7-2.9GHz band

We have assumed that the 2.7-2.9GHz band becomes available in 2021, once radar has been relocated from the band. As a sensitivity we have considered the case that there is a delay until 2025 in making the band available. This delay causes more new sites to be built in the period 2021-2024 (as there is less spectrum available for capacity), which reduces the demand for additional spectrum after this period. This translates to a decrease in the benefit of the 2.7-2.9GHz band to mobile services.

The result of this sensitivity is shown below in Figure 4-18.

Figure 4-18: Sensitivity on the timing of availability of the 2.7-2.9GHz band for mobile use [Source: Aetha]

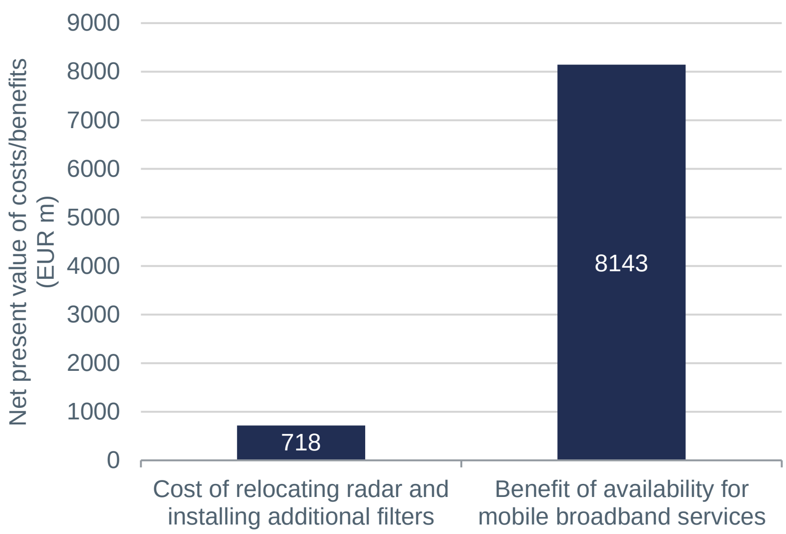


As Figure 4-18 shows, making the 2.7-2.9GHz band available for mobile services later, in 2025, reduces the benefit to mobile services from EUR8143 million to EUR7362 million.

5 Conclusions

This study on behalf of the GSM Association provides an initial assessment of the economic benefits of making the 2.7-2.9GHz band available to mobile broadband services in Western Europe. We have estimated separately the benefits of the band to mobile services and the costs to radar services currently operating in this band and in the 2.9-3.1GHz range if the band were to be made available to mobile services. A comparison of these is provided below in Figure 5-1.

Figure 5-1: Comparison of costs and benefits of making the 2.7-2.9GHz band available to mobile services in Western Europe [Source: Aetha]



As shown in Figure 5-1, we have estimated the benefit of the 2.7-2.9GHz band to mobile services as EUR8143 million and the cost to radar services as EUR718 million. This suggests that the benefit of making the band available to mobile services is approximately 11 times the costs that would be incurred by doing so.

Our assessment included sensitivity analysis, both on the radar costs and the benefits of the band to mobile services. This gives a range of estimates, based on the adjustment of key inputs and assumptions. The results of sensitivity analysis on the radar costs are summarised in Figure 5-2 below.

Figure 5-2: Summary of sensitivities on radar costs incurred if the 2.7-2.9GHz band is made available to mobile services [Source: Aetha]

Sensitivity	Net present value of costs (EUR m)
Base case	718
Military radar numbers scaled by civilian ATC radars	645
Military radar numbers scaled by population	792
Bird-strike radar numbers scaled by population	740
Military radars retuned to the 2.9-3.1GHz band	565
Meteorological radars need to be relocated from the band	949
Range of sensitivities	565 - 949

This sensitivity analysis suggests a range of estimates for the cost of relocating radars from the 2.7-2.9GHz band to an alternative band and installing additional filters to radars operating in the 2.9-3.1GHz band of EUR544 million to EUR949 million.

The results of sensitivity analysis on the benefits of the 2.7-2.9GHz band to mobile services are summarised in Figure 5-3 below.

Figure 5-3: Summary of sensitivities on the benefit of the 2.7-2.9GHz band to mobile services [Source: Aetha]

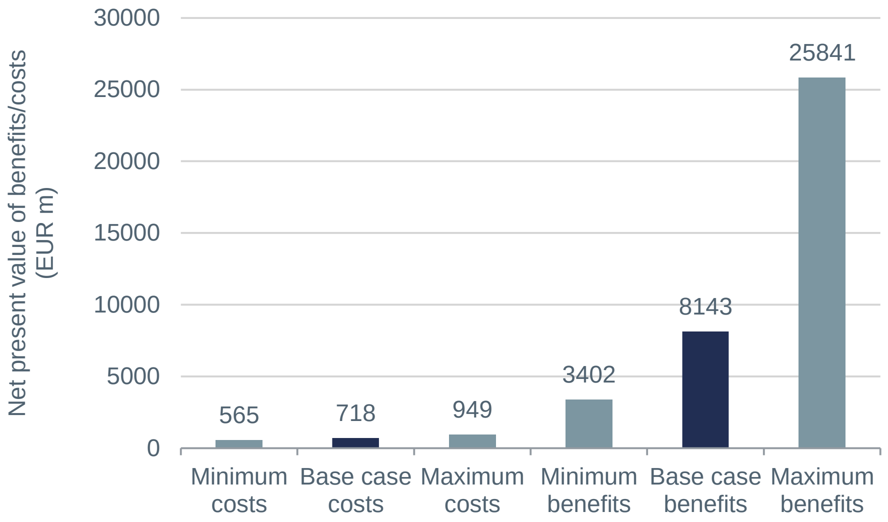
Sensitivity	Net present value of benefits (EUR m)
Base case	8143
Availability of the 3.5GHz band for mobile services	3402
Higher traffic levels than expected (2× traffic by 2035)	21 524
Traffic levels based on Cisco forecast	72 302
Lower long term spectral efficiency	11 541
Price elasticity of demand halved	6319
Price elasticity of demand doubled	25 841
Savings not passed on to consumers	5253
Timing of the availability of the band 2025	7362
Range of sensitivities	3402 - 72 302

This suggests a range of estimates for the benefit of the 2.7-2.9GHz band to mobile services of EUR3402 million to EUR72 302 million.

Note that the sensitivity analysis on the timing of the availability of the band (discussed in Section 4.4.6) suggests that the earlier that the band is made available, the larger the economic benefits. Indeed, if availability were to be delayed from 2021 to 2025, then approximately 10% of the benefit to mobile services would be lost.

The ranges of estimates discussed above are displayed below in Figure 5-4.

Figure 5-4: Range of estimates for the benefits and costs of making the 2.7-2.9GHz band available for mobile broadband in Western Europe[38] [Source: Aetha]



38 Note that we have not included the sensitivity based on the Cisco forecast in this figure, for ease of reading.

As can be seen in Figure 5-4, although the ranges are significant in size, the minimum estimated benefit of the band to mobile services is significantly higher than the maximum estimated radar costs (approximately 3.6 times higher).

Thus the conclusion of this assessment is that, provided that a new frequency range can be found for the radars, making the 2.7-2.9GHz band available for mobile broadband in Western Europe would maximise the economic benefits from this frequency band.

This study is intended as an initial estimation of the economic benefits, and therefore more detailed studies could be undertaken in order to provide more accuracy. However, the estimate we have calculated for the benefits is significantly higher than our estimate of the costs. Thus, although additional information/detail may result in a change to the quantitative results, the qualitative conclusion is very likely to remain. That is, the benefits will still outweigh the costs.

Annex A The 2.7-2.9GHz band in the Rest of Europe

In this Annex we present the methodology used for and results of a high-level estimation of the economic benefit of making the 2.7-2.9GHz band available for mobile broadband services in in the Rest of Europe[39]. This estimation has been calculated using a simple "extension" of the results for Western Europe, and should be treated only as an indicative estimate.

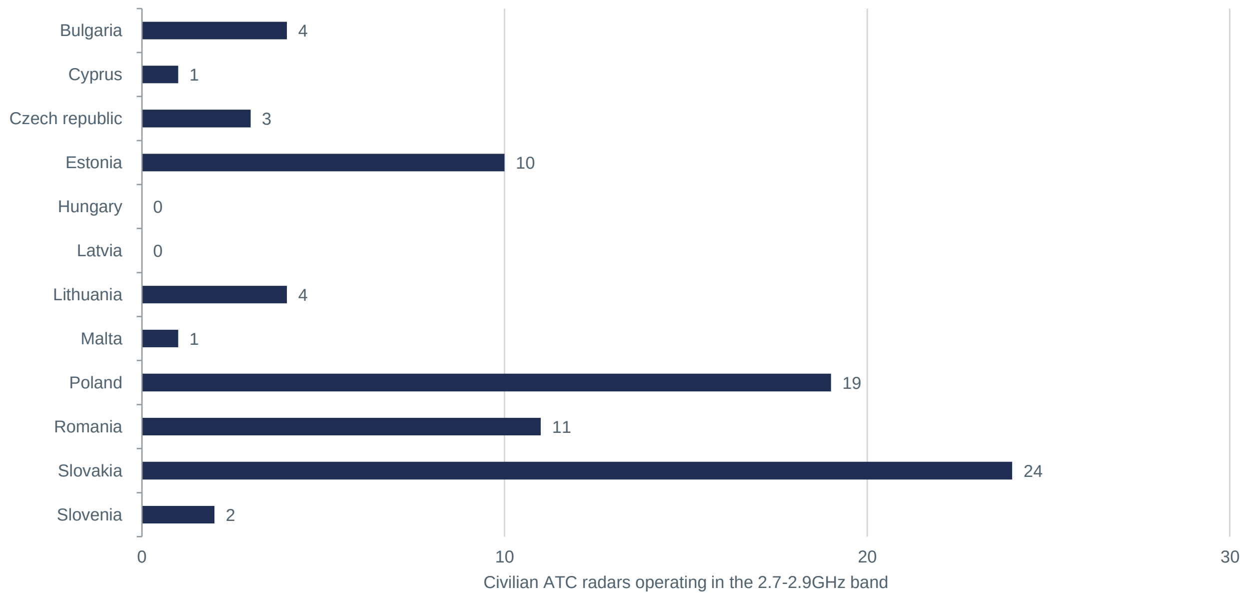
A.1 Methodology

To estimate the benefit of making the 2.7-2.9GHz band available for mobile broadband in the Rest of Europe, we have utilised the same methodology as for Western Europe, changing key inputs. The inputs we have altered for calculating the cost of relocating radars from the band and the economic benefit of the band to mobile services are discussed below.

A.1.1 Cost of relocating radar from the band

For countries in the European Union, civilian ATC radar numbers are available from the study for the European Commission[40]. These radar numbers are shown below in Figure A-1. To include those countries not in the European Union we have scaled up by the population of the Rest of Europe, as was undertaken for Western Europe.

Figure A-1: Civilian ATC radars operating in the 2.7-2.9GHz band [Source: WIK-consult[40]]



39 Within this report the Rest of Europe refers to Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Kosovo, Latvia, Lithuania, FYR Macedonia, Malta, Montenegro, Poland, Romania, Serbia, Slovakia and Slovenia.

40 '*Inventory and review of spectrum use: Assessment of the EU potential for improving spectral efficiency*', WIK-Consult study for the European Commission, 11 September 2012.

We have also utilised the military expenditure of the countries in the Rest of Europe, using 2012 data from SIPRI[41], in order to estimate the number of military radars.

We have assumed the same development costs and deployment costs per radar as for Western Europe. Note however that the development costs would only need to be incurred once if the 2.7-2.9GHz band was to be made available across the whole of Europe.

A.1.2 Economic benefits from use of the band for mobile broadband

In order to estimate the benefit of the 2.7-2.9GHz band when used for mobile services we have calculated the value for a representative country in the Rest of Europe (as was undertaken for Western Europe) and scaled up by the population of the Rest of Europe. To calculate the value for a representative country in the Rest of Europe we have utilised a lower ARPU forecast in line with current ARPU data from countries in the Rest of Europe. We assume the same trend as for Western Europe, but with a 2011 ARPU of approximately EUR12 per month per subscriber, based on data from a Merrill Lynch study[42].

We also planned to adapt the traffic forecast using data from the UMTS Forum report[43] for 2010, assuming the same trend as for Western Europe after 2010. However, we note that the UMTS Forum report seems to assume the same traffic usage per subscriber in a representative Western European country as for the whole of Europe in 2010. Hence the traffic forecast we have used is similar to that used for Western Europe. We note that in reality the traffic per subscriber in the Rest of Europe may differ from Western Europe, but for the purpose of a high-level estimate we have assumed 'base' traffic levels as detailed in the UMTS Forum report for 2010.

We also considered modifying the mobile penetration forecast. However, data from 2011[44] shows that mobile penetration at this time was approximately the same in Western Europe as in the Rest of Europe. We have therefore not changed this input.

A.2 Results

The results of our high-level estimation of the costs and benefits of making the 2.7-2.9GHz band available to mobile broadband services in the Rest of Europe are shown below in Figure A-2. Note that the cost of relocating radars shown includes development costs of approximately EUR156 million.

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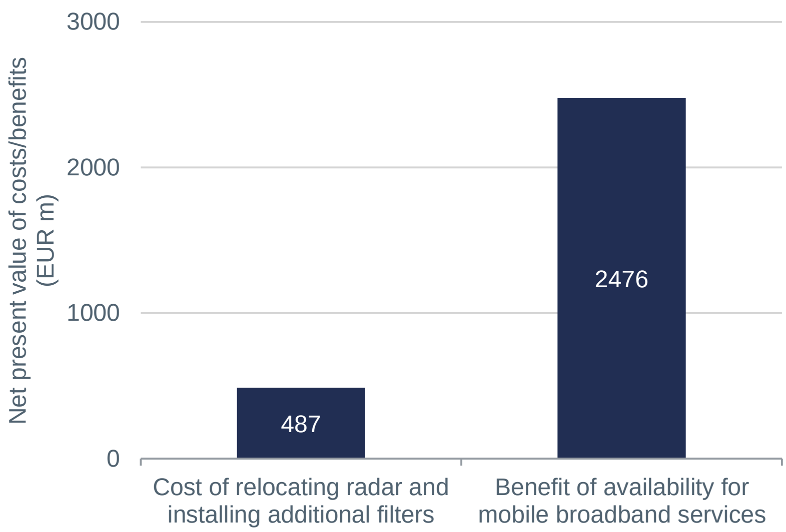
41 '*The SIPRI military expenditure database 1988-2012*', Stockholm International Peace Research Institute.

42 '*Global Wireless Matrix 3Q11*', Merrill Lynch, 28 September 2011.

43 '*Mobile traffic forecasts 2010-2020 report*', UMTS Forum, January 2011.

44 '*European Mobile Industry Observatory 2011*', GSM Association, November 2011.

Figure A-2: Comparison of costs and benefits of making the 2.7-2.9GHz band available to mobile services in the Rest of Europe [Source: Aetha]



As shown in Figure A-2 the benefit of availability of the band to mobile services (EUR2476 million) is significantly larger than the cost of relocating radar from the band and installing additional filters (EUR487 million).

The results suggest that the benefit of making the band available to mobile services in the Rest of Europe is approximately five times the cost incurred in doing so. This is a smaller, although still significant, multiple than for Western Europe (approximately 11.1), mainly due to the larger civilian ATC radar numbers for the Rest of Europe relative to population.

By combining these results with those for Western Europe we have an estimate of the benefits and costs for the whole of Europe[45]. An estimate for the radar costs for the whole of Europe, taking into account that development costs need only be incurred once, is then EUR1049 million. An estimate of the benefit of the band to mobile services for the whole of Europe is EUR10 619 million, i.e. the benefits are a multiple of 10 over the costs.

45 Here Europe refers to the countries in Western Europe and the Rest of Europe.