

Support to the 2GHz Impact Assessment – Final Report

Document information

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1 Introduction

1.1 Document purpose

This document is the final report and deliverable of the study conducted by Helios for the European Commission (under contract number 30-CE-0424943/00-32 SMART2011/0018) to support an Impact Assessment in light of the Commission's decision on the 2 GHz band.

In the context of this report the 2 GHz band refers to the 1920-1980 MHz band paired with the 2110-2170 MHz band for Frequency Division Duplex UMTS services (2 GHz FDD bands) and the 1900-1920 MHz and 2010-2025 MHz unpaired bands for Time Division Duplex UMTS services (2 GHz TDD bands).

The scope of this report is to summarise the results of a survey of 2 GHz stakeholders on their preferred options for use of the 2 GHz bands, and in particular the TDD bands, and a subsequent cost-benefit analysis to identify the use of the 2 GHz bands with the potentially greatest socio-economic benefit.

1.2 Study objective

The purpose of the study is to provide evidence to the European Commission (EC) to support an assessment of the impact of implementing a more liberal approach in the 2 GHz band by providing the following information:

- The future plans and views of current wireless service providers and network operators on how they would like to use the 2 GHz spectrum in the future.
 - In particular to provide feedback on the preferred option for more liberal use of the 2GHz band from the options identified by the EC.
 - To identify any additional preferred options for more liberal use of the 2 GHz band.
- Identification of barriers to the implementation of new services using the 2 GHz band.
- A quantitative analysis of the relative socio-economic costs and benefits of the preferred options for a more liberal use of the 2 GHz band.
 - Assess the impact of the early or late implementation of any policy changes.
 - Assess how cost and benefits vary between different stakeholders and geographic regions and the time to get a return on investment.
- Data, arguments and facts to back up the EC's final policy decision.

In parallel with this study the EC intend to prepare a full regulatory impact assessment. The results of this study will therefore feed into and inform the results of the Commission's impact assessment.

1.3 Background

The European Commission had harmonised at a European level the use of the 2 GHz band for UMTS in a Commission Decision pursuant to the provisions of the Radio Spectrum Decision. The European Commission has recently conducted a review of the regulatory framework in which implementing a new more liberal

spectrum management approach is a central issue for promoting more efficient use of spectrum and greater innovation in wireless services. The Wireless Access Policy for Electronic Communications Services (WAPECS) is the initiative within the European Union to allow more flexible use of spectrum for mobile, broadcasting, fixed wireless and other electronic communication services through the implementation of technology and service neutrality. The 2 GHz band has been identified for the application of the WAPECS concept by the EC and its Member States. .

To support a regulatory measure in the 2 GHz band the Commission is carrying out an assessment of the impact of the proposed new regulatory policy. The impact assessment is a logical set of steps to assess the potential economic, social and environmental consequences that the policy may have. The impact assessment helps the EC decide whether a new policy is worth implementing by preparing evidence for decision-makers on the advantages and disadvantages of the possible policy options.

WAPECS in the 2 GHz UMTS band

In Europe the 2 GHz band is allocated for use by UMTS FDD and TDD services. Specifically the 2 GHz band consists of the 1920-1980 MHz band paired with the 2110-2170 MHz band for FDD services and the 1900-1920 MHz and 2010-2025 MHz unpaired bands for TDD services. The use of the unpaired spectrum in the 2 GHz band however is currently low. The 2 GHz unpaired spectrum therefore potentially offers an opportunity to realise early benefits through the application of the WAPECS concept.

Enabling WAPECS in the 2 GHz band

The EC mandated the European Conference of Postal and Telecommunications Administrations (CEPT) to investigate how the WAPECS concept could be practically applied to the 2 GHz bands whilst taking into consideration the needs of existing services in the adjacent bands. Specifically, CEPT was tasked to develop common and minimal (least restrictive) technical conditions which would allow non-UMTS FDD and TDD technologies and services to co-exist in the 2 GHz band with UMTS. Allowing non-UMTS technologies and services to use the 2 GHz spectrum while applying the CEPT technical conditions will potentially enable early WAPECS benefits to be realised while protecting the rights of the existing users of the spectrum.

Additional considerations of CEPT technical conditions

The constraints specified in the CEPT Report 39 for use of the 1900-1920 MHz band are generally more constraining than the current licence conditions. However, the EC would prefer to relax the conditions mentioned in CEPT Report 39 so that at least current licence conditions would remain to promote more efficient use of the 2 GHz band and promote technical innovation. A key issue is when more relaxed licence conditions could be implemented.

There may be a risk of fragmentation in the use of spectrum if conditions mentioned in CEPT Report 39 for 1900-1920 MHz are circumvented through national measures in order to achieve higher power limits in these bands. It is important that the EC works closely with network operators and service providers to ensure harmonised use of the band to mitigate any additional coordination and costs required for use of the band which might further inhibit its use.

1.4 Study methodology

The European Commission has initiated this study to support an impact assessment through a survey of stakeholders in the 2 GHz band and a quantitative analysis of the relative socio-economic costs and benefits of the preferred options for more liberal use of the 2 GHz band.

An overview of the study methodology is given in Figure 1-1 below. The key to understanding the socio-economic impact and conducting the Cost-Benefit Analysis (CBA) is identifying the likely services that will be provided in the liberalised regime. Therefore Task 1 identified the likely strategies of the service providers in the liberalised regime while Task 2 identified the most likely technical options for use of the 2 GHz TDD bands, including an assessment of the technologies that could be used to provide services in the liberalised regime under the conditions specified in the CEPT report. This information was then used to qualitatively assess the most likely scenarios for service provision in the liberalised regime, taking into account effects such as cross-border coordination. The 4 most likely scenarios were then assessed in more detail within Task 3 to quantify their relative socio-economic costs and benefits using a CBA model developed in MS Excel under Task 4. Under Task 5 the results of the initial analysis were written up into a draft report which was then subject to expert review by the Commission and the project team. Following this review the analysis was optimised and re-run to produce the results for the final report.

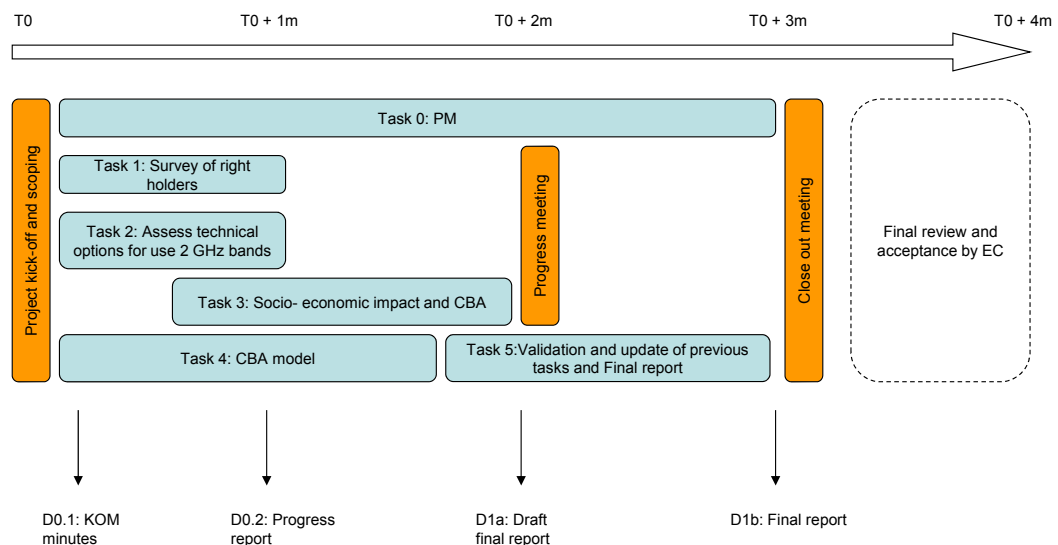


Figure 1-1: Study approach

Key to the study methodology was the survey of stakeholders (including wireless service providers, network operators and equipment manufacturers) and the CBA itself. The survey of stakeholders provided feedback on key questions posed by the EC and informed the scenarios analysed in the CBA. These two activities are described in more details in the following sections

1.5 Document Structure

The remainder of this document is structured as follows:

- Section 2 describes the survey of stakeholders that was conducted including a summary of the key observations that were made.

- Section 3 describes the results of the assessment of the technical options for the future use of the 2 GHz band.
- Section 4 describes how the CBA was conducted, the key assumptions made and presents the results and key observations for each scenario investigated.
- Section 5 presents the results of a sensitivity analysis conducted in the CBA results.
- Section 6 presents an overview of the key results from the study.
- Section 7 presents recommendations to the EC on what options for the use of the 2 GHz band would result in the greatest socio-economic benefit with the evidence to support the EC's Impact Assessment.

2 Survey of 2 GHz Licence Holders

2.1 Purpose

A stakeholder survey was conducted in order to address specific questions posed by the EC, to identify the likely services that would be provided in a liberalised regime and to identify technologies that could be used in the 2 GHz band under the conditions specified in the CEPT report. The results of the survey were used to help define the specific options for use of the 2 GHz band analysed in the CBA.

Specifically the purpose of the survey was to:

- identify how stakeholders would like to use the 2 GHz band in the future;
- identify the extent to which there is sufficient stakeholder interest and sufficient manufacturer momentum to stimulate the growth of new services in the unpaired 2 GHz TDD bands;
- identify any barriers to the implementation of new services in the 2 GHz band;
- assess the impact of implementing the CEPT technical conditions on the existing right holders in the EU in the 2 GHz band;
- assess technologies that could use the 2 GHz band (and in particular the TDD bands) under the technical conditions specified in the CEPT report;
- provide feedback on the preferred options for more liberal use of the 2GHz band.

In particular regarding the CEPT technical conditions the survey also aimed to answer the following specific questions:

- What can be done now with the 2 GHz band using the technical conditions specified in the CEPT report?
- Is it possible to do anything now using more relaxed technical conditions than those specified in the CEPT report?
- What can be done that has minimum impact on existing infrastructure above 1920MHz?

2.2 Approach

The survey was primarily aimed at existing 2 GHz licence holders within Europe but also considered more widely wireless service providers, network operators and equipment manufacturers. Two survey questionnaires were produced (included in Annex C): one aimed at service providers and network operators; and one aimed at equipment manufacturers. These were used to capture information against specific questions as well as to facilitate discussions during interviews with specific stakeholders

Research was carried out to identify contact details for owners of 2 GHz licences across Europe. Based on this research the survey was sent via post to 76 licence holders. In addition to the postal survey interviews with the following organisations were set up based on contacts held by either the study team or the EC. The telephone interviews provided an opportunity to have more detailed and wide ranging discussion concerning the options and issues for the future use of the 2 GHz band and therefore provided significant additional value to the survey. Table

2-1 below identifies the organisations that were approached for interview and which interviews took place.

Organisation	Type	Interview method
O2	Network operator	Telephone
Vodafone	Network operator	Face-to-face
RIM	Equipment manufacturer	Contact made but no detailed comments received.
Nokia Siemens (Note 1)	Equipment manufacturer	Telephone
Qualcomm	Chipset manufacturer	Telephone
IP Wireless	Equipment manufacturer	Telephone and face to face
Alcatel-Lucent	Equipment manufacturer	No response
Samsung	Equipment manufacturer	Responded by email
INTEL	Equipment manufacturer	Contact made but no detailed comments received.
Orange	Network operator	Email
SFR	Network operator	Responded by email
Huawei	Equipment manufacturer	Expressed an interest but did not respond in time
GSM Association	Network operator representative	Contacted, but deferred response to member of one of their working groups.

Table 2-1: Organisations approached for interview

Note 1: the interview with Nokia Siemens also involved contacts in China who had knowledge and experience of the implementation of TD-SCDMA in the TDD bands in China.

2.3 Summary of results from survey of 2 GHz licence holders

The questionnaire results from the survey of 2 GHz licence holders were collated using a web-based survey tool (www.surveymonkey.com). Specifically, 20 separate responses (or partial responses) were gathered from the following organisations:

Organisation	Country
Mobitel/Telekom	Slovenia
T.2.d.o.o	Slovenia
Tango SA	Luxembourg
Orange	Austria, France, Romania, UK
Elisa	Finland
Telefonica	Slovakia, UK
Deutsche Telekom	Germany
Telenor	Denmark
DNA Ltd	Finland
EMT AS	Estonia
KPN	Netherlands
Telia Danmark	Denmark
Telcom Italia	Italy
Vodafone	On behalf of Vodafone operating companies in Europe
Bouygues Telecom	France
DECT	ETSI Technical Committee on behalf of the European DECT licence holders and community

Table 2-2: Organisations responding to licence holder survey

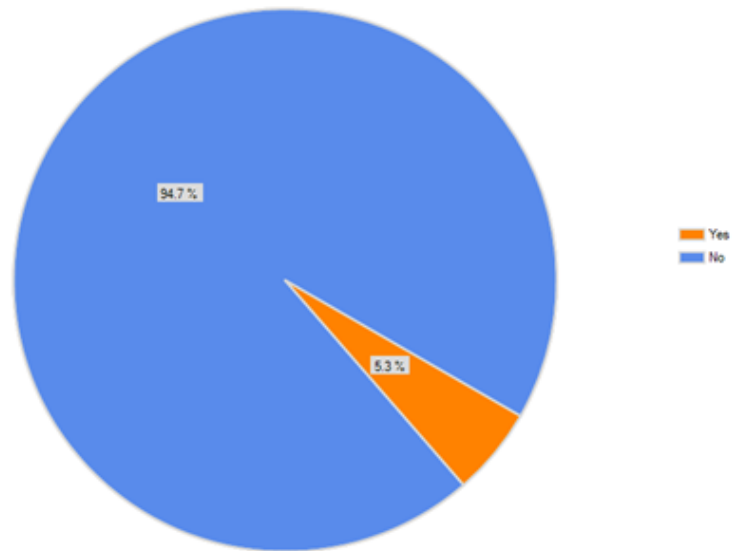
A summary of the responses to each question in the survey is provided below.

Q1: What is your current spectrum assignment in the 2 GHz bands (paired and unpaired) and what date does it expire?

The typical response was 2 x 15 MHz FDD and 1 x 5 MHz TDD with expiry dates in the range 2017 to 2026.

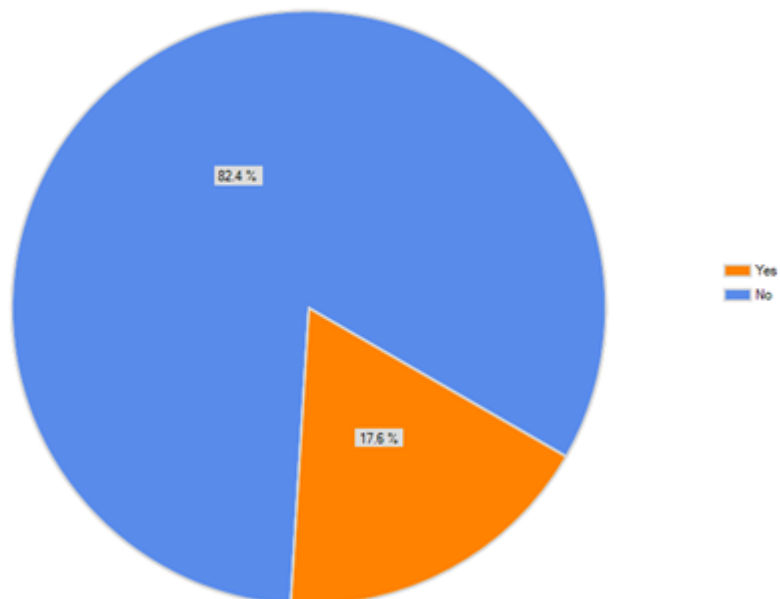
Q2: Do you currently operate any services in the unpaired spectrum (1900-1920 MHz and 2010-2025 MHz)?

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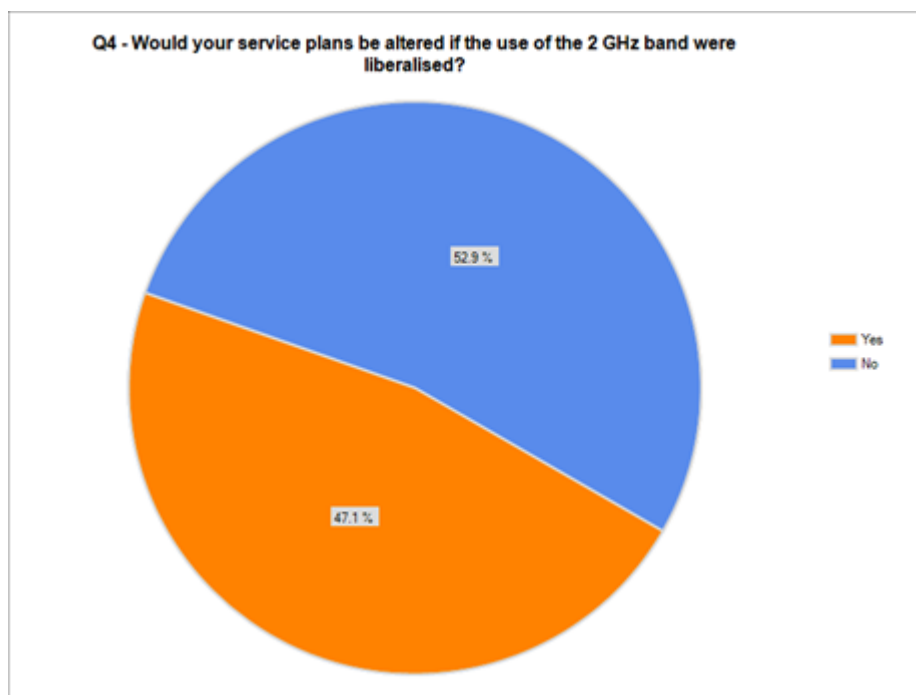


Q3: Do you have any plans to utilise this spectrum in the near future?

Q3 - Do you have any plans to utilise this spectrum in the near future?



Q4: Would your service plans be altered if the use of the 2 GHz band were liberalised?



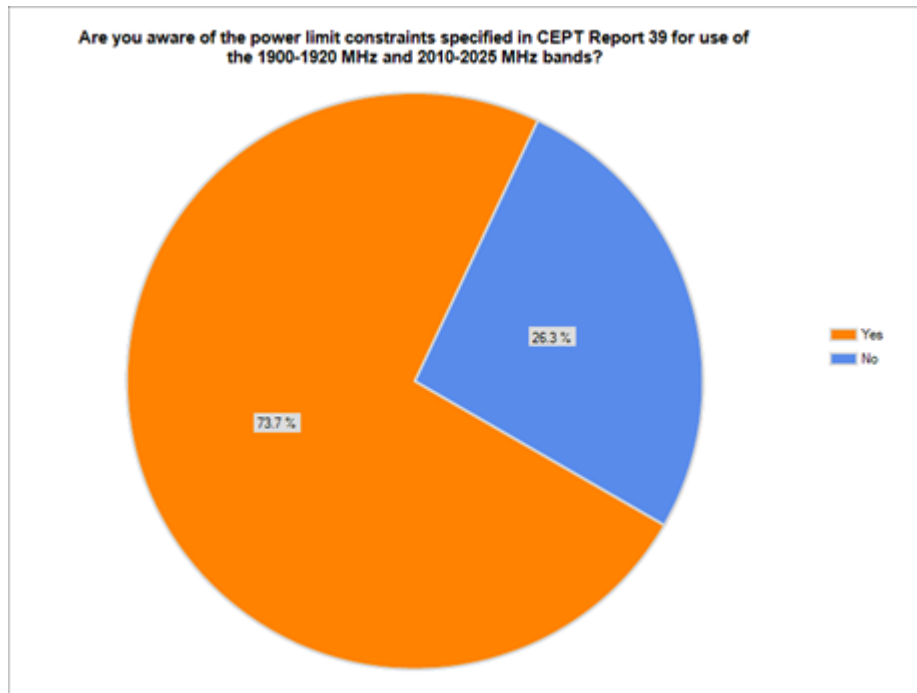
Q5: What kind of services would you envisage the 2 GHz bands being used for in the future?

The typical answer was high speed mobile broadband and voice with TDD bands potentially supporting asymmetrical services.

Q6: What do you perceive is the added value of harmonising the use of 2 GHz band for the use of technologies other than UMTS?

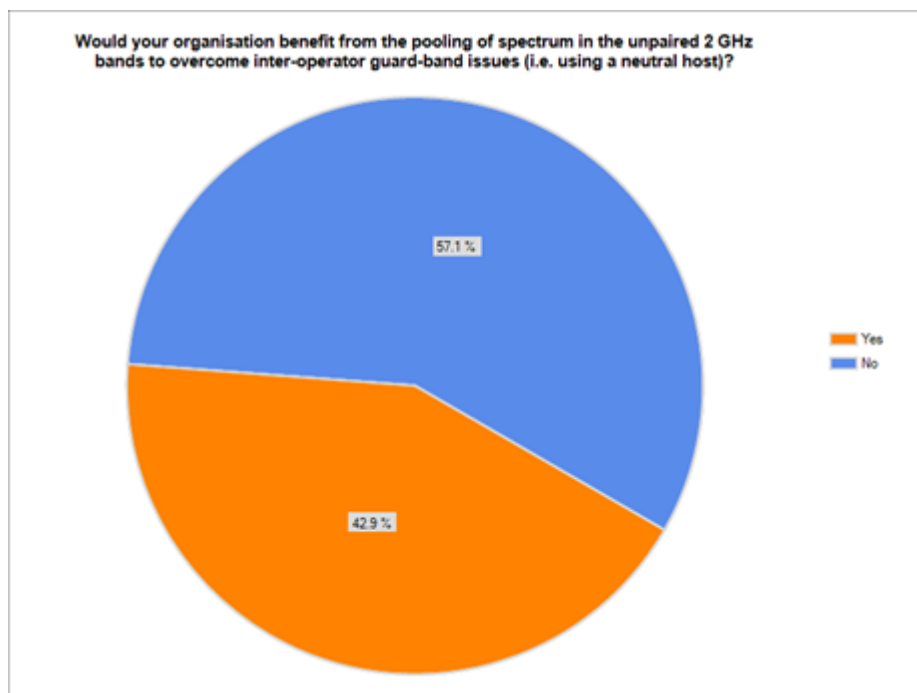
The typical answer was earlier introduction of LTE, broad availability of devices to utilise spectrum and potential economies of scale.

Q7: Are you aware of the power limit constraints specified in CEPT Report 39 for use of the 1900-1920 MHz and 2010-2025 MHz bands?



The typical view of the in-band power limits is that they are restrictive (i.e. would result in restricted cell site coverage) but necessary to protect the heavily used FDD spectrum. Less restrictive in-band power limits may result in increased interference in FDD bands and/or additional costs to mitigate interference (e.g. filters) but could potentially enable a wider range of technologies and services.

Q8: Would your organisation benefit from the pooling of spectrum in the unpaired 2 GHz bands to overcome inter-operator guard-band issues (i.e. using a neutral host)?



Q9: What % increase in service revenue would your organisation likely see following liberalisation of the use of the 2 GHz bands?

The typical view was that in the short term that value was 0 and in the long term it was unknown. However, it was suggested that a cost benefit case may exist for asymmetric services in the TDD band.

Q10 - Please indicate your TOP TWO preferred options for the future use of the 2GHz bands from the options below. (1 = most preferred option; 2 = next preferred option.)

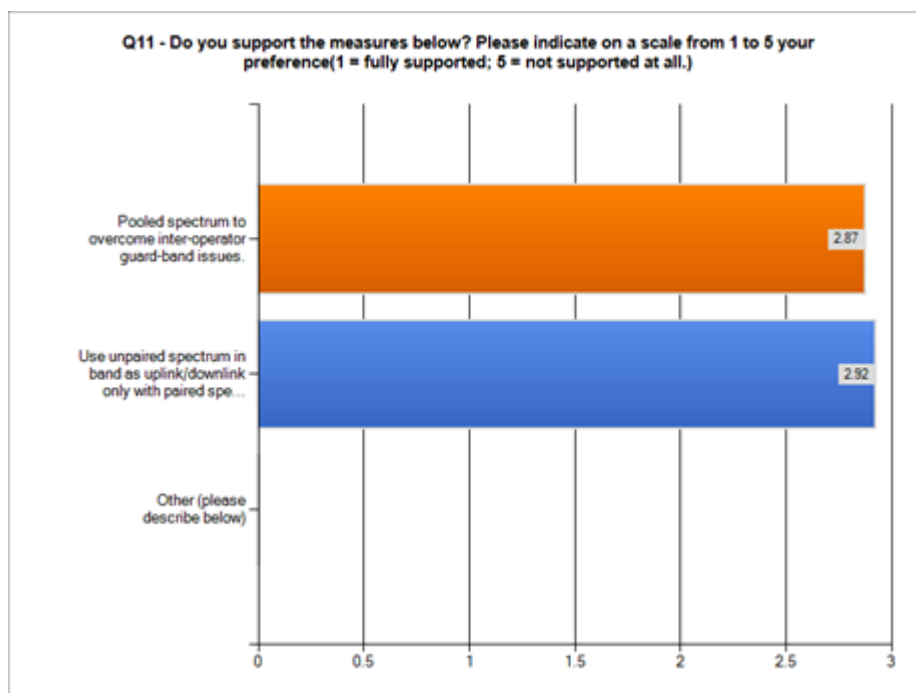
As illustrated in the table there appears to be a slight preference for the options "Technical harmonisation with LTE" and "No change".

	Number of responses indicating option as:		Total responses
Option	Preferred option (1)	Next preferred option (2)	
Technical harmonisation with LTE as the only additional standard with a mandatory EU wide allocation.	5	4	9
No change – future use of 2 GHz band is the same as current use.	5	3	8
The implementation of service and technology neutrality in the band through later policy implementation (with the option for earlier action at a national level).	2	5	7
Implementation of service and technology neutrality in the band through early policy implementation.	2	4	6

Q11 - Do you support the measures below? Please indicate on a scale from 1 to 5 your preference (1 = fully supported; 5 = not supported at all.)

The figure below shows the average rating for the following proposed measures and illustrates that no clear trend emerged from the survey.

- Pooled spectrum to overcome inter-operator guard-band issues.
- Use unpaired spectrum in band as uplink/downlink only with paired spectrum in another band (and if so which ones?).
- Other.



Other comments

It was noted that the pooling of spectrum is closely related to spectrum trading and sharing.

Spectrum sharing should be based on mutual agreement between mobile network operators but should not be a regulatory obligation.

The pairing of the 2 GHz unpaired spectrum with spectrum in another band has been considered before but up to now there has been no need to develop this in practice. However any options for pairing the 2 GHz unpaired spectrum should also now be considered in the context of increasing asymmetrical data traffic.

It is important to avoid discrimination of operators not having TDD licence due to liberalisation.

The most efficient outcome for the spectrum band 2010 – 2025 MHz is award to a single licensee since this removes the need for block edge masks.

2.4 Summary of results from survey of 2 GHz equipment manufacturers

The questionnaire results from the survey of 2 GHz equipment manufacturers were collated from completed questionnaires returned by email. Specifically, 5 separate responses (or partial responses) were gathered from the following organisations:

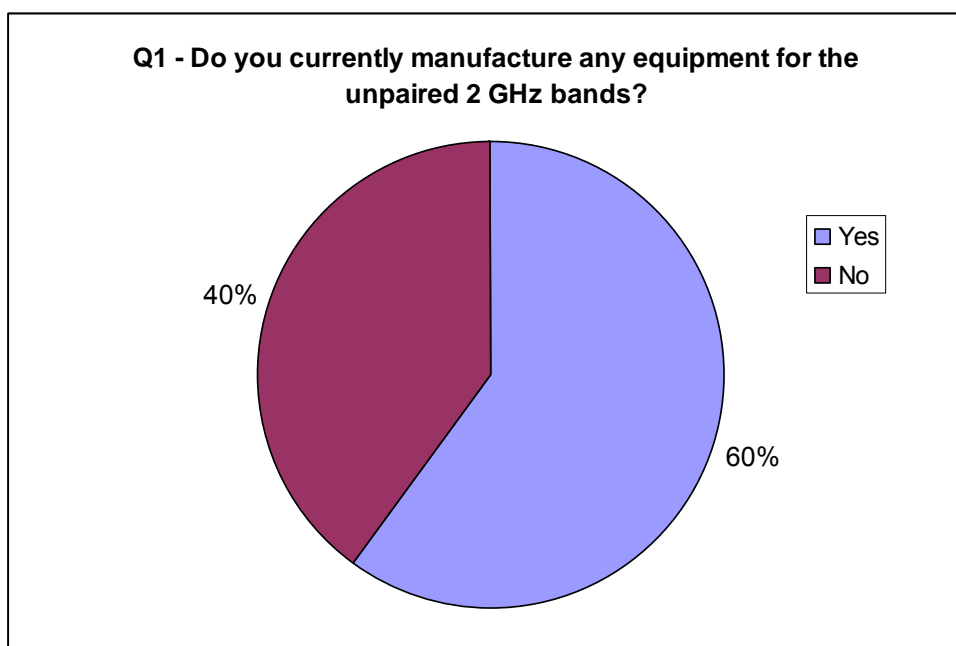
Organisation	Country
Qualcomm	Europe, Middle East, North Africa
IP Wireless	UK
Nokia Siemens Networks	On behalf of European operations

Organisation	Country
Samsung Electronics	UK
Ericsson	Sweden

Table 2-3: Organisations completing equipment manufacturer survey questionnaire

A summary of the responses to each question in the survey is provided below.

Q1: Do you currently manufacture any equipment for the unpaired 2 GHz bands?



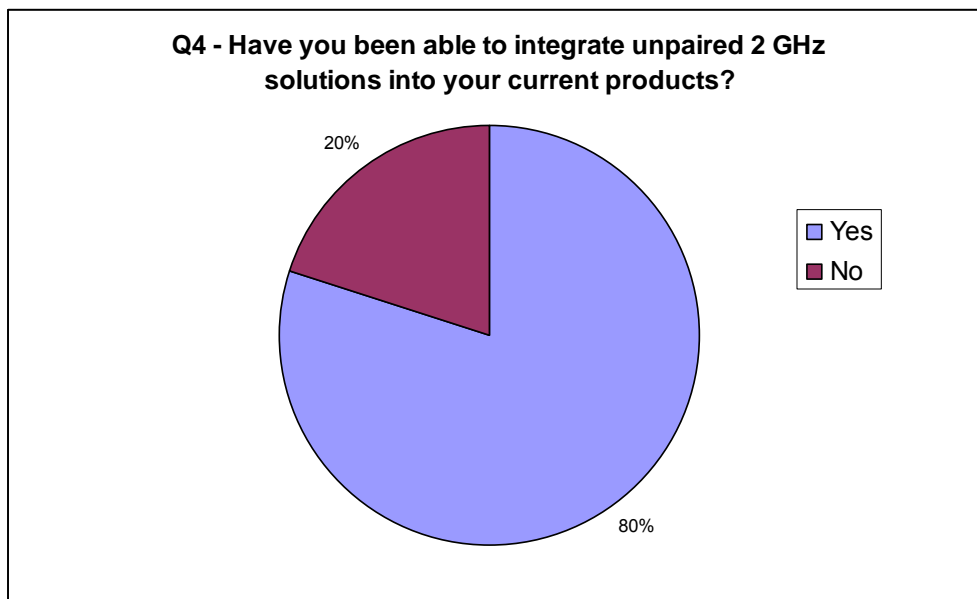
Q2: How successful have these products been in comparison to other equipment operated at 2 GHz?

In general, existing products have only been successful in limited geographical areas, for example Eastern Europe or China. This was supported by a particular need for wireless broadband infrastructure. Therefore, success has been limited in scope. Cost was also seen as a limiting factor.

Q3: How do the costs of these products differ from other equipment operated at 2 GHz and in other bands?

These products are generally more costly than standard FDD world market products, due to smaller economies of scale and costly operation requirements. However, due to the lack of commercial products it is difficult to tell whether this cost would reduce with increased volumes of equipment.

Q4: Have you been able to integrate unpaired 2 GHz solutions into your current products?



It is noted that integration does not indicate that commercial products are available. Integration into commercial products would be subject to demand and cost efficiency.

It has also been noted that the current regulatory situation has limited the success of integration of systems.

Q5: How soon and for which technologies would you see suitable equipment becoming available following liberalisation of the 2 GHz band?

This is generally believed to be dependent upon sufficient market demand. Demand could drive the relatively quick deployment of these technologies, subject to modified regulatory conditions, since products containing the technologies are already available.

Liberalisation is not necessarily required to enable technology development since new technologies (such as LTE, IMB) are already commercially deployed or are in trial stages.

Q6: What do you perceive is the added value of harmonising the use of 2 GHz band for the use of technologies other than UMTS?

If LTE is regarded as a technology other than UMTS then the result may be very positive. LTE will eventually be used in several frequency bands across Europe and the World (in addition to 2 GHz) therefore maximising the benefits from use of the technology.

It is noted that technology neutrality is important in spectrum regulation, but LTE is generally seen as likely to be the most successful technology.

Q7: Are you aware of the power limit constraints specified in CEPT Report 39 for use of the 1900-1920 MHz and 2010-2025 MHz bands?

All respondents indicated that they were aware of the power limit constraints specified in CEPT Report 39.

It was noted that the power limits specified in CEPT Report 39 would limit deployment and prevent the use of wide area services. Some therefore see low power supplementary indoor use as the best economical prospect for unpaired 2 GHz TDD bands.

It was stated that the costs of implementing these power limits are likely to outweigh the potential benefits. Less restrictive power limits are generally believed not to significantly increase interference, but greatly increase the cost benefits for manufacturers

Applying significantly different power limits to blocks of spectrum may also create technical and legal difficulties, leading to a fragmentation of the system. It must be ensured that the use of the unpaired 2 GHz TDD bands does not limit the use of the paired 2 GHz FDD bands.

Q8: What increase in revenue would your organisation likely see following liberalisation of the use of the 2 GHz bands?

In the short term, 0% increase in revenue is expected due to availability of other more attractive options (e.g. newly assigned spectrum in 800 MHz and 2.6 GHz bands). Mid- and long- term changes in revenue are possible, but cannot be predicted at this stage.

Q9 - Please indicate your TOP TWO preferred options for the future use of the 2 GHz bands from the options below. (1 = most preferred option; 2 = next preferred option.)

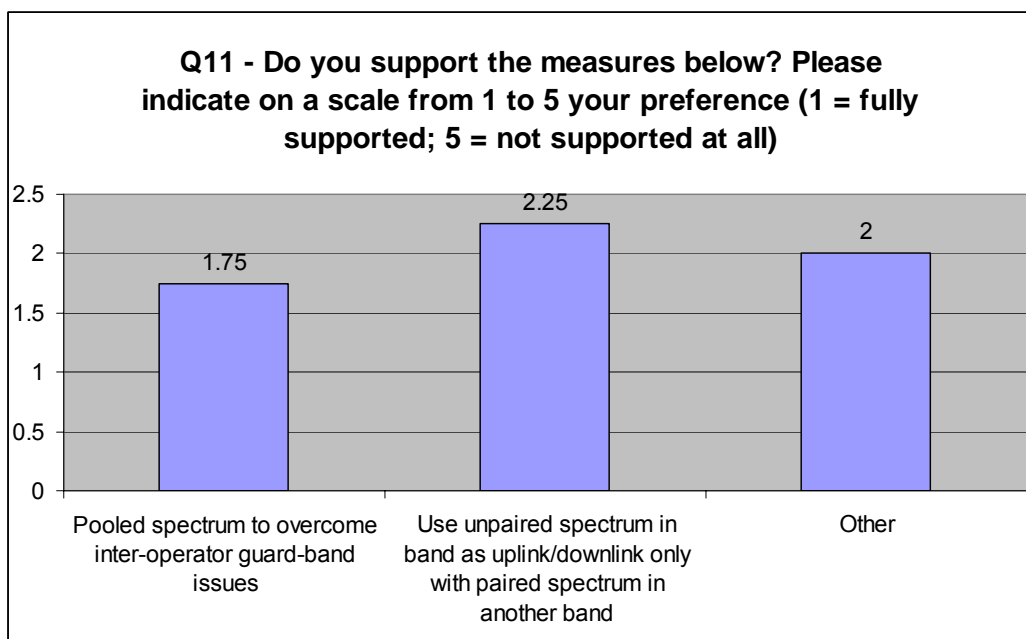
As illustrated in the table below no clear trend emerged from the survey responses.

	Number of responses indicating option as:		Total responses
Option	Preferred option (1)	Next preferred option (2)	
Technical harmonisation with LTE as the only additional standard with a mandatory EU wide allocation.	1	1	2
The implementation of service and technology neutrality in the band through later policy implementation (with the option for earlier action at a national level).	1	1	2
Implementation of service and technology neutrality in the band through early policy implementation.	1	1	2
No change – future use of 2 GHz band is the same as current use.	1	0	1

Q10 - Do you support the measures below? Please indicate on a scale from 1 to 5 your preference (1 = fully supported; 5 = not supported at all.)

The figure below shows the average rating for the following proposed measures and illustrates that no clear trend emerged from the survey.

- Pooled spectrum to overcome inter-operator guard-band issues.
- Use unpaired spectrum in band as uplink/downlink only with paired spectrum in another band (and if so which ones?).
- Other.



Other suggested options were to identify credible harmonised usage of band to favour the emergence of a harmonised and large scale market.

Other comments

It was noted that a modified regulatory framework which allows for coexistence of adjacent bands is the necessary next step to improve utilisation of spectrum.

2.5 Key observations from survey

Considering the objectives of the study the following is a summary of key trends and conclusions that emerged from the survey.

Future use of 2 GHz band

- In the future the 2 GHz FDD and TDD bands will be used as additional capacity to support existing services i.e. mobile broadband and voice. However, it was recognised that the TDD bands would be particularly suitable for supporting the cost effective delivery of asymmetrical services including broadcast.

Barriers to implementation of new services using 2 GHz band

- Barriers to use of TDD are primarily due to the lack of business case or market for delivering services using the TDD bands rather than for technical reasons (i.e. there is still additional FDD spectrum available that is more economically viable as a means for meeting increasing capacity demands).
- There is no strong market demand (yet) for services requiring or benefiting from TDD. It is unlikely that a business case would exist for a new operator to use TDD bands as an infrastructure investment will not be economically justified to ensure cost-effective delivery of services.
- TDD bands are seen as additional capacity for current mobile services provided by Mobile Network Operators (MNO). However, there is still spare capacity within FDD bands which is seen as more commercially attractive by the MNO and where their efforts are focussed.
- The main demand is for wideband services and both the 1900-1920 MHz and the 2010-2025 MHz bands are too small to be useful (e.g. due to guard-bands). Spectrum pooling¹ and spectrum trading² are options being looked at by MNOs where smaller (e.g. 5 MHz) assignments can be combined to create a single larger spectrum block in order to facilitate greater bandwidths within 1900-1920 MHz and 2010-2025 MHz but may require Europe wide coordination.
- There is potential interference between legacy FDD equipment because original 3GPP standards did not take into account use of TDD 1900-1920 MHz band³ adjacent to the FDD 1920-1980 MHz band when defining the FDD base station filter requirements.
- For the 1900-1920 MHz band a 5 MHz guard-band may be required at both ends of the band to prevent interference on TDD terminals operating in the band from UMTS FDD terminal in the adjacent band above and DECT terminal in the adjacent band below. This would severely limit the usable spectrum within the 1900-1920 MHz band.
- Use of TDD bands must support (MNO) economies of scale and not impact the development of FDD bands.

Implications of the technical conditions specified in the CEPT report

- The typical view of the in-band power limits is that they are too restrictive to be useful (i.e. would result in restricted cell site coverage) but necessary to protect the heavily used FDD spectrum.
- Less restrictive in-band power limits may result in increased interference in FDD bands and/or additional costs to mitigate interference (e.g. filters) but could potentially enable wider range of technologies and services.

¹ Spectrum pooling is where licensed users combine their spectrum into a contiguous block and operate a single network in the combined spectrum.

² Spectrum trading permits licensed users to buy, sell and lease their spectrum to other users.

³ In particular the use of the block 1915 – 1920 MHz is likely to be heavily restricted due to the need for a guard band to prevent interference with FDD base stations operating in the adjacent 1920 – 1980 MHz band.

- Some of the assumption and conclusions of the report were also questioned. There is also the opinion that some information had been missed or not given the relevant attention which is important for coexistence issues between synchronized and unsynchronized TDD systems, and compatibility issues between adjacent band cellular systems.
- Overall it was considered that the report conclusions would potentially inhibit emergent technologies in the unpaired TDD bands.

Stakeholder feedback on liberalisation of the 2 GHz band

- The support was evenly spread between the 4 liberalisation options identified in the survey questionnaire with slightly stronger support for the 'LTE harmonisation' option.
- Complete liberalisation is not necessarily required to facilitate the use of the TDD bands. Technologies and services meeting current licence conditions can already be used in the TDD bands e.g. mobile broadcast services based on the Integrated Mobile Broadband (IMB) 3GPP standard. In addition harmonised use of the TDD bands will be required in order to overcome the limitations associated with their narrow bandwidth (e.g. through spectrum pooling/trading or transmission synchronisation in order to facilitate larger channel sizes). Harmonisation itself will in turn reduce the potential flexibility in the use of the 2 GHz TDD bands.
- There is general support for the use of LTE in the 2 GHz bands. LTE TDD and FDD will be implemented in the same chipset and will be implemented in high end phones in 1 to 2 years. However, use of the capability in phones/handset devices will depend on selected RF components.
- One stakeholder suggested that early indication on future use of band for LTE would help de-risk operator implementation plans. However, early liberalisation would not accelerate changes or solve the issue with the lack of use of the TDD bands due to its narrow bandwidth.

3 Technical Options for Use of 2 GHz TDD

3.1 Introduction

The 2 GHz FDD bands will continue to be used for the core mobile and data services provided by MNOs and this was backed up through the survey responses received. However, the use of the 2 GHz TDD band is subject to debate.

This section therefore identifies the most likely options for use of the 2 GHz TDD bands based on the results of the survey, the assessment of available technologies, different policy options and an analysis of the use of the 2 GHz bands. The results of this analysis form the basis for the scenarios considered in the CBA in section 4.

3.2 Overview of the 2 GHz bands

The bands under consideration in this study are those shown in orange and dark green in Figure 3-1; however it is important to understand the wider spectrum context into which they fit.

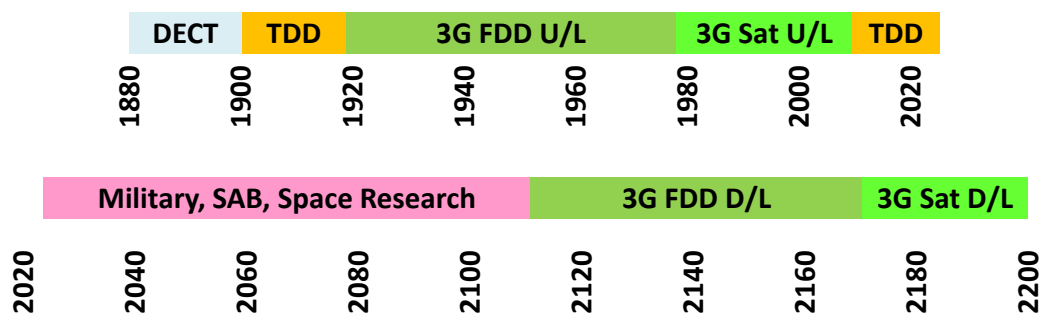


Figure 3-1: Current assignment of frequencies in the range 1880–2200 MHz

The band 1900 – 1920 MHz sits adjacent to the band 1880-1900 MHz which is used across Europe for DECT services⁴. DECT services have *‘priority over other services in the same band, and are protected in the designated band’*. In addition EC Decision 2009/766/EC requires that UMTS and GSM systems operating in adjacent bands give DECT appropriate protection (note that GSM base stations already operate at frequencies up to 1880 MHz). The basic assumption is that out of band power emissions should be in compliance with the UMTS spectrum emission mask below 1900 MHz and is reflected in the CEPT report. However, where UMTS TDD terminals are used in the vicinity of a DECT site the CEPT report also indicates that DECT will be required to create at least a 5 MHz dynamic guard band within its own allocation at the 1900 MHz border. While DECT is capable of this dynamic guard band it will be at the expense of loss of capacity. In addition the DECT community also notes the potential for interference from DECT terminals on UMTS TDD terminals operating at the 1900 MHz border. The band also sits adjacent to the current 3G uplinks in the band 1920-1980 MHz.

⁴ As per EC Decision 91/287/EEC and ERC DEC (94)03 on the frequency bands to be designated for the coordinated introduction of DECT system into the Community.

The band 2010-2025 MHz is adjacent to the band 1980-2010 MHz which is designated as an uplink band for satellite based 3G services⁵ though these may be supplemented by a ground component (e.g. terrestrial relays or fill-in). It is also adjacent to services in the band 2025-2110 MHz which are often military in nature, including both links and satellite services, noting that tactical links are harmonised within the range 2025-2070 MHz. The band is also used for services ancillary to broadcasting (SAB)⁶, notably video links. Further, there are satellite services, for example, NASA's TDRS satellites and the Meteosat satellites which have uplinks in the band and which have to be protected.

3.3 Policy options

The different policy options available fall into three distinct scenarios:

- 'Do nothing'. In this scenario, the use of the spectrum will be as described in current licences and will be restricted by those licence terms.
- 'Liberalise'. In this scenario, the recommendations of CEPT Report 39 would be implemented and the spectrum liberalised on a harmonised basis at EU level to permit the use of additional technologies (e.g. LTE), though it is worth noting that at least one country (Germany) has already taken this step in recent auctions
- 'Pair'. In this scenario, the TDD bands would be paired with other spectrum in order to yield additional FDD spectrum.

Each of these policy options presents technical and regulatory challenges. These challenges are described in more detail below along with the most likely scenarios for use of the unpaired 2 GHz spectrum under each option.

3.3.1 Option A: Do nothing

The use of the unpaired 2 GHz TDD spectrum in this scenario is driven by existing licence terms (i.e. restricted to UMTS). These typically permit high power use (though there are examples of countries like Germany and Switzerland which already have, or are in the process of implementing, liberalised terms based on the application of the technical conditions specified in CEPT 39). Two operational scenarios would be likely in this scenario either the use of the bands for TDD services; or the use of the bands for IMB services.

The use of the bands for TDD services is heavily restricted either by adjacency to the 2 GHz FDD uplink band (in the case of spectrum below 1920 MHz) or by the need for severe restrictions in output power (or complex inter-operator co-ordination, or the fitting of expensive channel filters) required to permit adjacent frequency use. It seems very unlikely that the bands would be used for TDD services in this scenario, a view supported by operators. It is worth recording, however, that the synchronisation of networks is not technically complex or expensive, and that the split between downlink and uplink is not likely to vary

⁵ As per EC Decision 2007/98/EC and ERC DEC (06)09 on the harmonised use of the bands 1980 – 2110 MHz and 2170 – 2200 MHz for the implementation of Mobile-Satellite Service including those supplemented by a Complementary Ground Component (CGC).

⁶ As per ERC REC 25-10 on frequency ranges for the use of temporary terrestrial audio and video SAB links.

significantly between operators such that reaching an agreement on how many timeslots to dedicate to each direction should not prove overly controversial.

The most likely outcome of a do nothing scenario would be the use of the bands for IMB services. IMB use is permitted within existing licence terms, however the downlink-only nature of the service means that it cannot be used in the 5 MHz block immediately adjacent to 1920 MHz due to the need for a guard-band with the FDD uplink band. Further, it requires all operators with spectrum in the band to agree to use IMB, otherwise power levels will be severely restricted. It is also worth noting that the use of the band for this purpose may be also be restricted (in terms of available bandwidth and power levels) in order to prevent interference into the neighbouring DECT band at 1880-1900 MHz, in particular where DECT is used for enterprise applications and therefore antennas may be mounted in prominent locations. In theory, the whole of the band 2010-2025 MHz could be used for IMB services.

The FDD bands would continue to be used as they currently are with operators making use of any, as yet, unused capacity to meet increased demands.

3.3.2 Option B: Liberalise

The use of the unpaired 2 GHz spectrum in this scenario would remain nominally TDD in function, but the potential technology uses would expand (e.g. the use of LTE). The implications of the implementation of CEPT Report 39 are to reduce the maximum permissible transmitter power significantly, but allowing increases if co-ordination between operators takes place. The resulting TDD network in this instance may bear little difference to that in the do nothing scenario in that instead of co-ordinating power levels down to an acceptable compromise, they would be negotiated up. The end result is likely to be very similar.

Similarly, the IMB option (expanded to include for example the LTE based EMBS) would still stand.

The additional flexibility offered by the liberalisation of the bands would be the use of alternative technologies in both the TDD and FDD bands (e.g. TD-LTE and FD-LTE). One of the benefits in the particular case of LTE is that the core of LTE remains around 90% common between the FDD and TDD variants and it is apparent that chipset manufacturers producing LTE silicon are producing units that inherently have both FDD and TDD capability but use of this capability is still dependent on the selection of the RF components within the handset.

The RF costs in a handset will increase with the number of different bands and technologies that need to be supported. However, cost reductions due to economies of scale can be achieved if the number of handsets sold is sufficiently high. Therefore, in order to keep costs down for supporting a technology and/or bands in a handset it is important to demonstrate the demand for its use. In addition the harmonised use of technologies and/or bands may also help stimulate demand for their use as well as reduce the complexity and cost of the RF components. Feedback from equipment manufacturers is that handsets supporting both TD-LTE and FD-LTE are feasible and can be built at a reasonable cost if there is sufficient demand⁷. Thus the additional cost (in handset terms) of

⁷ There is also evidence to suggest that the cost of RF components (of a similar complexity) decreases over time. The RF bill of materials costs for a tri-band phone was ~\$12 in 2003, while for a similar volume of units the bill of materials for a quad-band phone in 2006 was ~\$6.

incorporating TDD functionality is vastly reduced compared to the current UMTS situation where the handset chipsets only support FDD.

Similarly, for base stations equipment manufacturers already have the capability to offer TD-LTE on the same baseband unit as FD-LTE subject to the demand for its use.

3.3.3 Option C: Pair

The option to pair the TDD spectrum with another band in order to make it FDD is only feasible where there is spectrum with which to pair it. A number of bands have been suggested for the paired element however all of these suffer from significant regulatory and licensing issues. They are:

- 1452-1492 MHz. This spectrum is currently assigned to broadcasting services and is intended for digital audio broadcasting. The lower 27.5 MHz of spectrum (1452-1479.5 MHz) is set aside for high power terrestrial broadcasting but the remainder is set aside for satellite broadcasting services and thus, for terrestrial use, would be heavily restricted in power levels. There has been little to no roll-out of broadcast services in this band in Europe. Clearly this does not offer sufficient spectrum to pair both TDD bands. In addition, the spectrum is not adjacent to an existing mobile band and as such, new antennas may be required in user equipment (though it has been suggested that as it is close to GNSS frequencies, the antenna used for receiving GNSS could be re-used for reception of this band).
- 2090-2110 MHz (to be paired with 1900-1920 MHz only). This band would be a very straightforward pairing, retaining the duplex spacing of existing 3G networks. The spectrum however, currently has a variety of uses, including space science and space operations and so extensive protection of satellite services is necessary in the band. Any change in use of this spectrum would need to be approved by the World Radiocommunication Conference (WRC).
- 2585-2620 MHz. This would provide sufficient spectrum to pair both 1900-1920 and 2010-2025 MHz bands (used as uplink) and is adjacent to an existing high power downlink band. However, the use of this band is already subject to an EC Decision on 2.6 GHz. Much of this band has been (or is being) licenced for TDD services as part of the 2.6 GHz auctions taking place across Europe (and more widely). As such, in order to use it as a pair, some existing licences would need to be revoked. In addition, the use of the band for downlink would reduce the duplex gap in the 2.6 GHz band from 50 MHz to 15 MHz. This would require tighter filtering in the handset and is likely to result in a reduction in sensitivity.
- 15 MHz from 1900 – 1920 MHz (used as uplink) together with 2010 – 2025 MHz (as downlink). As with several other options, the main issue is that these bands are already licensed, typically to different operators (i.e. an operator will have an assignment either in 1900 – 1920 MHz or 2010 – 2025 MHz but not both). Therefore, the existing licences would need to be revoked or spectrum trading would be required in order to realise this pairing. In addition the relatively close spacing of the uplink and downlink frequencies (i.e. between the upper end of the uplink band at 1980 and the lower end of the TDD band as used for downlink, 2010 MHz) may require more complex RF component and filter design than is currently used. Finally the number or size of resulting FDD channels available will be smaller compared to the other options due to the smaller amount of spectrum being used.

Which (if any) of these options proves the most feasible will, in the first instance, depend upon the extent to which the spectrum necessary for pairing could be made available. Where it is already licensed (e.g. 2.6 GHz) but not used, in theory the use of spectrum trading could permit operators to re-organise their assignments but there is no guarantee that such arrangements would be or could be reached. In the case of the 1.4 GHz band, where this spectrum has already been licensed to broadcasters, there may be significant regulatory impediments to recovering it for other use. However if it is not in use, and if spectrum pricing were applied to the band, there may be a natural desire from broadcasters to return the spectrum⁸. It is also worth noting that the concept of pairing the 2 GHz TDD spectrum with other unpaired spectrum has already been intensively discussed but lacks the wider support of the industry. Network operators will again seek to use additional capacity currently available from existing FDD spectrum before considering additional pairing options.

3.4 Identification of scenarios for CBA

The purpose of the Cost Benefit Analysis (CBA) is to assess the relative socio-economic benefits for each scenario representing the most likely uses of the 2 GHz bands and the potential impact that any policy decision on liberalisation will have on these benefits (e.g. through enabling new technology). Each scenario is assessed against a baseline “Do nothing” scenario in which the 2 GHz licence conditions do not change.

From the above discussion, and based on the feedback from the survey, the following scenarios for the use of the 2 GHz spectrum have been selected for more detailed analysis in the CBA:

- “Option A: **Do nothing**” represents the reference baseline scenario for the CBA.
- Three feasible uses of the TDD bands have been identified under “Option B: Liberalise”. These are the harmonised use of the TDD bands for:
 - High power services such as **macro cells** based with the associated necessity for inter-operator co-ordination and negotiation.
 - Low-power services such as **femto cells** without inter-operator co-ordination or negotiation.
 - **Downlink only** (e.g. IMB/EMBS) **services** to support asymmetric data transfer.
- The use of the TDD bands for uplink, paired with a downlink in another band as identified in “Option C: Pair” to provide additional **FDD services**.

In each of the above scenarios the 2 GHz TDD bands are used as additional capacity by the MNOs to provide mobile voice and broadband data services similar to those currently provided today. This was the most widely supported use of the 2 GHz TDD bands by the current 2 GHz licence holders and is therefore the most likely future use of the TDD bands (any change in use of the bands would require the agreement of the existing licence holders and the licences to potentially to be re-issued).

⁸ Note that in the UK, this spectrum was awarded through auction by Ofcom to Qualcomm and thus would not be available for these purposes without their agreement.

In the above scenarios it is also assumed that the FDD bands are used in a similar manner as they currently are now. The FDD bands are key to the provision of mobile network operators' core services of high speed mobile broadband and voice. Any liberalisation of the 2 GHz would need to protect the core services provided in these bands but also support the evolution of the band. Primarily the MNOs are looking at the use of LTE in these bands to achieve greater efficiency in the use of its spectrum and higher data rates. Therefore, in the "Do nothing" scenario it is assumed that there will be continued use of UMTS in the FDD bands to provide core services until all the available capacity has been used. In the remaining scenarios it is assumed that the MNOs will switch from UMTS to LTE in the first instance following liberalisation to achieve greater spectrum efficiency and capacity.

The baseline and each of the 4 identified scenarios are discussed in more detail below.

3.4.1 Baseline scenario: Do nothing

This scenario assumes that the 2 GHz licence conditions will not change and that there is no policy decision on liberalisation. Therefore use of the band will be based on UMTS as it is now⁹. Due to costs of upgrading handsets and the lack of market for a service using the TDD bands it is assumed that there will only be a very small amount of use of the TDD bands based on IMB.

3.4.2 Scenario 1: Macro cells - high power TDD

In this scenario, the TDD band in question is used for high power TDD macro (or micro) cell networks to deliver voice and data services as currently provided in the FDD band. These high power macro cells would need to be synchronised and the uplink/downlink apportionment agreed between operators. Feedback from the survey suggests the traffic profile for different MNOs is likely to be similar and therefore synchronisation is feasible although it should be noted that this would potentially inhibit future innovation by individual MNOs.

The result is a requisite increase in wide-area network capacity. If it is assumed that each 1 MHz of TDD spectrum is roughly equivalent to 0.5 MHz of FDD spectrum (due to the need for uplink and downlink to share the same frequency), a 5 MHz TDD service would provide the equivalent additional capacity of 2.5 MHz of FDD spectrum.

Note that for a network in which a user is currently enjoying a full (2 x) 5 MHz FDD channel, handover to a 5 MHz TDD channel could potentially have an impact on the quality of service provided. Further, with the use of aggregated channels (such as is achievable with HSPA+ and LTE), it is feasible that a user on an FDD network may enjoy a service provided by greater than (2 x) 5 MHz of FDD spectrum making the change in service quality even more noticeable - much would depend upon the number of users on the cells.

Integration into handsets is difficult using UMTS as it would require the addition of an extra chipset, however following a move to LTE, the cost is almost negligible as future chipsets will support both TD and FD-LTE.

⁹ It is noted that in some countries it is already possible to use LTE based on the implementation of more liberal licence conditions. However, for the purposes of the CBA the baseline case has been assumed to consider only the use of UMTS.

Therefore in this scenario we assume that TDD-UMTS will not happen as it is not currently supported in chipsets and that operators will wait for the introduction of TD-LTE where TD-LTE will already be supported in those chipsets which will be integrated into the majority of handsets. Coordination would then be required between operators on the transmissions powers used and the uplink/downlink organisation of the channel to mitigate any interference.

3.4.3 Scenario 2: Femto cells – low power TDD for indoor/home use

In this scenario, the band is used for low power TDD femto cell networks to again deliver voice and data service as currently provided in the FDD band. Depending on deployment, these would not necessarily need to be synchronised as the low power nature of the infrastructure would produce low enough adjacent channel interference to permit uncoordinated operation.

A network of this type may be used to provide additional capacity in tightly defined areas such as in homes, offices and confined spaces (such as railway stations) through the use of very small cells. In these cases it is also possible that the femto cells will be built in other products used in the home such as wireless routers and that existing internet connections at the cell site locations (e.g. at home) will be used to provide the backhaul of data to the MNOs network backbone. In order to maximise the benefit from this scenario it is assumed that there is wide-spread implementation of femto cells, including areas with existing (wide-area) network coverage. It is assumed that in this scenario it is the availability of dedicated spectrum and thus lack of potential to cause interference to, and degrade the service of, existing networks, that encourages the rapid take-up of femto cells. Therefore, for this analysis, the use of femto cells is not assumed in other scenarios.

It is likely that femto cells will be also deployed without the use of the TDD bands in the way envisaged in this scenario, and thus this scenario represents an upper bound for their likely impact if used in the 2 GHz TDD band. With sufficient coordination, femto cells could re-use frequency bands used for the wide-area network although this can increase the complexity of network design and frequency allocation.

Like in the macro cell scenario above it is assumed that TDD-UMTS will not happen as operators will wait for the availability of TD-LTE compatible handsets.

3.4.4 Scenario 3: Downlink only services - asymmetric data transfer

In this scenario, the band is used for (high power) downlink only services to support asymmetric data transfer. This would provide additional downlink capacity which is particularly beneficial where a number of users request or require the same content. Such content could include both real-time and non-real time data including common audio or video data, common web-sites, application updates, and push¹⁰ data services.

This scenario could be implemented on a per operator basis using their existing spectrum or across multiple operators sharing pooled spectrum. The delivery of common content via a downlink only network reduces the load on the original

¹⁰ Push services are often based on information preferences expressed in advance. A client might "subscribe" to various information "channels". Whenever new content is available on one of those channels, the server pushes the information out to users.

network by a factor equal to the number of users who are requesting the data in question. For example, if 4 users in a cell (belonging to a single MNO) were streaming the same multimedia content, the transfer of this content to the downlink only network would free up all 4 downlinks and replace it with just 1. Where content is common between operators, the operation of a downlink only service provides even greater benefits (i.e. there are likely to be more users streaming the same content), allowing even more common content to be offloaded from the original network(s). Alternatively, by pooling spectrum higher bandwidths could potentially be achieved compared to implementation on a single operator basis.

Although push data services can be delivered over current FDD bands it is not efficient to do so, particularly if they are bandwidth intensive. Using the TDD bands for downlink only could provide a cost efficient way of delivering high bandwidth push data services. This in turn could stimulate and allow the development of a range of new applications and services for users (beyond the current voice and data services) that are currently not feasible.

In addition the technical challenge of providing a seamless service while handing over between TDD and FDD cells (when moving to an area without TDD coverage) has already been successfully overcome and demonstrated. However, it is noted that in order to fully support non-real-time push data services handsets may need to be modified to cache the received data for use at later time when requested by the user.

As with the other scenarios, integration into handsets becomes much more straightforward under an LTE scenario due to the likely availability of compatible handsets, but is costly for UMTS and potentially WIMAX (current implementations rely on external 'dongles' to access IMB services). Therefore, while there may be a small amount of use of IMB, it is assumed that if the band is liberalised to allow the use of LTE operators will mainly wait until the availability of the LTE based EMBS.

3.4.5 Scenario 4: FDD services - uplink only in TDD band paired with downlink in another band

In this scenario, the TDD band(s) are used for uplink, paired with a downlink in another band. It is important to note that, at present, there is no straightforward pairing option, though the use of 1452-1492 MHz or 2090-2110 MHz may be feasible in the medium term, subject to regulatory and commercial discussions and constraints.

In this scenario, additional wide-area network coverage can be provided and each 5 MHz channel will yield the same additional capacity as any other (2 x) 5 MHz FDD channel.

3.5 Additional considerations

3.5.1 Fragmentation due to limited TDD bandwidths

A key limitation on the use of the TDD bands is that they are narrow in bandwidth compared to other bands available. In order to overcome the resulting difficulties and limitations (e.g. to prevent interference) greater coordination and harmonisation of their use is required to avoid fragmentation. This in turn will reduce flexibility.

Any of the scenarios identified above could be implemented whether the band is liberalised or not, however the liberalisation (e.g. the application of CEPT 39) will offer a more rapid means for operators to use services based on new-technologies such as LTE. Under current licensing regimes, some operators may be able to roll-out LTE services without a change in their conditions, whereas others may not. This fragmentation would be solved through a harmonised Europe wide liberalisation decision.

Whilst, in theory, it would be possible for each operator to take a stand alone decision as to which of these scenarios to implement, there are clearly technical impediments which would serve to restrict flexibility in the case where operators wished to go their own way. For example, an operator could not introduce IMB services in spectrum adjacent to another operator who wished to offer TDD services due to the high levels of interference into the TDD service. Similarly one could not operate an uplink in spectrum adjacent to a downlink. As such, it seems highly unlikely that operators with adjacent spectrum would be able to provide different services from the above list. In practical terms, this means that all operators in a specific band would need to offer the same services (including, in the case of TDD, substantially the same apportionment of timeslots between uplink and downlink).

A similar situation occurs in cross-border instances. If an operator on one side of a border had a high power IMB network, it would be unfeasible for an operator on the other side of the border to operate a TDD network in the vicinity of the border. Even cross-border interference agreements would not overcome these issues other than to severely restrict the operation of services on both sides of a border.

There is therefore a question as to the extent to which any operator has the flexibility to select a technology solution independent of other operators and of neighbouring countries. The upshot of this is that, in general, the first movers in using the bands will set a precedent for the overall use of the band, curtailing the flexibility of others. It is, however, feasible that the services operated in the 1900 – 1920 MHz band could differ from that in the 2010 – 2025 MHz band providing a modicum of flexibility.

In addition it has been suggested by several organisations, that the band 2010 to 2025 MHz should be licenced to a single operator. The use of the band for TDD networks introduces significant co-ordination requirements which devalue the utility of the band. In addition, the band is not truly 15 MHz wide due to the need for guard-bands to prevent interference into adjacent bands. Typically licences are allocated to three or more operators in a country. Therefore, one or more operators could end up with an assignment that is smaller than 5 MHz in size. This may have limited utility inasmuch as a block of less than 5 MHz is insufficient to support a full UMTS carrier. Though it could support a smaller LTE carrier (e.g. 3 MHz bandwidth) this would be relatively inefficient leaving some parts of the band unused.

3.5.2 Machine-to-Machine communications

It is also noted that all scenarios¹¹ potentially also support Machine-to-Machine (M2M) data communication where each machine becomes a terminal device on the mobile network and the MNO's infrastructure is used to route data between machines. Depending on the M2M requirements (i.e. location of machines, amount of data, and time of transmission) this could lead to specific cell-site becoming overloaded. As machines are typically located in offices or at home the use of femto cells in scenario 2 is therefore a particularly effective way of managing this type of M2M communication by spreading the load across the cell-sites.

An alternative use of the TDD bands to support M2M communication is also discussed in sections 3.6 and 3.7 below. Section 3.7 also discusses the additional benefits that may arise from supporting a M2M application.

3.6 Other potential scenarios

Other potential scenarios identified (during the survey, wider research and subsequent analysis) for use of the TDD bands for services other than mobile broadband are listed below. These scenarios do not have the same level of support as the scenarios above and for any near term implementation would also require buy-in from all existing licence holders to allow the spectrum to be used for services other than mobile broadband. These scenarios are therefore listed here for reference only and are not analysed in the CBA.

- Backhaul from cell sites (potentially non line-of-sight). With the growth in demand for data, having access to such spectrum could provide significant economic benefits to operators.
- M2M communications using mesh networking and similar to support local communications.
- Use of the spectrum for a bespoke CNI/PPDR¹² network in support of blue-light and similar services. This is similar to what has been done in New York where similar spectrum has been set aside for such services.
- An expansion of licence-exempt bands to permit further innovation in service provision (as per the existing 2.4 GHz band).
- Use of the spectrum for high speed wireless local loop, acting as the 'last 100 metres' for fibre-to-the-kerb networks.

This type of alternative use of the TDD bands could result in different benefits compared to its use as additional mobile network capacity proposed by the existing licence holders. To illustrate these different types of potential benefits a qualitative analysis of the use of machine-to-machine communications using mesh networking is presented below.

¹¹ Scenario 3 does not directly support two-way M2M data transfer (because it is downlink only). However, M2M is indirectly supported as scenario 3 frees up capacity from the FDD networks which can be used to support M2M.

¹² The chairman of CEPT ECC Frequency Management PPDR Project Team 38 has expressed a need for spectrum but currently the preference is for spectrum below 1 GHz.

3.7 Qualitative analysis of M2M communications using mesh networking

3.7.1 Introduction

If the 2 GHz TDD bands were used for M2M communication it is likely that one application could be the development of smart meters and associated technology, together referred to as smart grid. As an example of how the value might be realised in such a scenario, smart grid technology has been used to develop an alternative scenario, which is presented below.

The most likely implementation of smart grids is using mesh networking where data is routed directly (peer-to-peer) between machines (and not necessarily via the MNO infrastructure). In this case the 2 GHz TDD bands are assumed to be used to provide the direct communication between machines. This is a different use of the TDD bands than the additional capacity for MNOs which is assumed for the scenarios identified in section 3.4 above.

Alternatively, M2M communications can also be realised under scenario 2, whereby different appliances communicate with each other via femto cells and the central MNO infrastructure acting as any other end-user equipment such as a mobile phone or a dongle in the cellular network.

There are, of course, many other potential applications within the concept of M2M communications which underpin, for example, the Commission's 'Internet of Things' goals.

3.7.2 Example scenario: smart grid

Since the inception of electricity deregulation and market-driven pricing throughout the world, utility companies have been looking for a means to match consumption with generation. Traditional electrical and gas meters only measure total consumption and as such, provide no information of when the energy was consumed, nor provide any signals for consumers to take decisions about their own usage. Smart meters provide an economical way of measuring usage information and transmitting it back to the energy provider, allowing price setting agencies to introduce different prices for consumption based on the time of day and the season and then communicating this back to users in real time. In addition electronic devices could themselves communicate with the smart meters for information on energy prices and intelligently alter their energy consumption in line with the current energy generation and price of energy.

From a consumer perspective, smart metering offers a number of potential benefits to householders. These include:

- an end to estimated bills, which are a major source of complaints for many customers;
- a tool to help consumers better manage their energy use - smart meters with a display can provide up to date information on gas and electricity consumption in the currency of that country and in doing so help people to better manage their energy use and reduce their energy bills and carbon emissions;
- a means for consumers (or their devices) to take decisions as to when to consume energy as a way to reduce their bills.

It is estimated that there are 57 million energy meters (with a further 10 million water meters) in the UK alone. Providing connectivity to these devices faces a number of challenges not least due to their indoor location. However, one likely

solution is the combination of a mesh-network (where each smart utility meter communicates peer-to-peer with any other smart meter in range) and a cellular network (providing access points for the mesh network to the wide area network and therefore connectivity to the energy provider). The number of access points - primarily pico or femto cells due to transmission power constraints - required to provide coverage for the great number of mesh network devices is likely to be comparable to that required for country-wide cellular coverage with high capacity.

The data load on the access point would be relatively small for UMTS (3G) or LTE/WIMAX (4G) cellular networks. The MNOs will therefore be able to use their existing networks to provide the necessary data connectivity for access points. In this context the 2 GHz TDD bands would be used to provide the peer-to-peer M2M communication between the smart meters as part of the mesh-network. The required power levels and bandwidth requirements for each connection in the mesh-network would be relatively low, fitting in with the current limitations on the use of the 2 GHz TDD bands. However, the potential interference between cellular devices and meshed devices would also need to be assessed.

3.7.3 Costs, benefits and barriers of a smart grid scenario

There are likely to be two main impacts on consumers and firms of using the 2 GHz TDD bands in this way:

- The cost of supplying energy over the long term is likely to fall as capital labour substitution implies the task of meter reading and billing will become much more automated. Potentially (part of) this cost-saving will also be passed on to end users in the form of reduced energy prices.
- In addition to the above, the information provided to the energy supplier on usage patterns will enable them to better tune their generation to consumption and thus reduce the need for excess provision, reducing capital costs of new supply plant, simplifying distribution and evening out consumption. This would further lower supply costs.
- Smart meters may allow consumers more choice of supplier and allow energy companies to charge differential prices depending on factors such as time of day, price of wholesale electricity, wind speed, etc. Having greater choice of tariff, more information and easier switching should give consumers greater welfare but also make it easier for firms to price discriminate and charge consumers more when they have a higher willingness to pay.

In assessing the costs and benefits of using such smart meters it is also important to consider repercussions of changes in prices and volumes of carbon emissions. Reductions in price may lead consumers to use more energy than otherwise (e.g. by pushing lower priority usage into times where supplies are cheaper, but not reducing consumption at peak times), leading to changes in carbon emissions. However, if greater flexibility in pricing allows more efficient use of (relatively intermittent) renewable energy, such as wind, thus saving on the base carbon-intensive energy (e.g. coal), it could alter the energy mix in a way that reduces carbon. In general, it is recognised that smart grid technologies should offer an overall reduction in carbon footprint, but that this may not all occur at the consumer premises.

The main costs and barriers to enable smart grids include:

- the costs associated with the equipment production of the “pico cell” and access points for the mesh network;

- the costs associated with equipment manufacturers obtaining the licences to use the 2 GHz TDD bands;
- a significant number electronic devices using the mains supply (in the home/office) may be required to be communicated with the smart meter in order to maximise the benefits from increased efficiency in energy use.

The benefits of implementing smart grids could apply to a wide range of stakeholders:

- **MNOs:** The MNOs could realise additional revenue from the data transmitted to and from the cellular network and the mesh-network via the access points without any significant additional infrastructure investment (for the MNO).
- **M2M equipment manufacturers:** Smart grids would potentially enable a new market, essentially using existing equipment and technologies, with associated new revenue streams and potential job creation.
- **Energy suppliers:** Smart grids could enable more proactive and cost-effective energy generation that more closely matches consumption needs, this in turn could lead to increases in producer surplus.
- **Consumers:** More cost-effective production of energy and more intelligent pricing with a greater choice of tariffs could result in either consumer benefits associated with reductions in energy prices or due to an increased ability to select energy products that most closely match their needs.
- **Environmental:** Ultimately smart grids could enable reduction in carbon emissions. The cost associated with reduced carbon emissions is heavily rooted in society's perception of the importance of environmental factors which can change with time. The social cost of carbon is therefore difficult to estimate accurately however, current estimates suggest a value of the order of 100€ per tonne of carbon.

In terms of comparing this type of use of the 2 GHz TDD bands with the mobile broadband data scenarios identified in section 3.4 the following comments can be made:

- The size of the consumer base for energy supply is of a similar order of magnitude compared to the consumer base for mobile data services.
- The number of different stakeholders that could potentially benefit from the smart grid scenario described above is greater than the number of stakeholders considered in the mobile broadband data scenarios.
- There is the potential for a much greater societal benefit from the smart grid when considering the potential impact on the environment through the reduction of carbon emissions.

4 Cost benefit analysis

4.1 Purpose

The purpose of the Cost Benefit Analysis (CBA) is to identify which of the scenarios identified in section 4 has the greatest relative socio-economic benefit and the impact that the timing of any policy decision on liberalisation will have on these benefits. Specifically each of the scenarios is to be assessed against the baseline “Do nothing” scenario in which the 2 GHz licence conditions do not change.

4.2 Approach and assumptions

4.2.1 Introduction

This section provides an overview of the approach taken to conducting the CBA which was implemented in an Excel based model. The Excel model was setup so as to allow CBA input parameters and assumptions to be easily changed and the analysis to be quickly re-run.

In addition any specific assumptions made in conducting the CBA are described.

4.2.2 Calculating socio-economic benefits

Economic benefits from enabling or facilitating the use of currently unused or under-utilised spectrum can derive from:

- enabling new services to be provided;
- alleviating capacity constraints in relation to the delivery of existing services; or,
- more efficient delivery of existing services.

Based on feedback received through stakeholder survey questionnaires and interviews the most likely use of the 2 GHz bands is to provide additional capacity for the existing networks to provide mobile broadband services and in particular the delivery of data to consumers. This increase in capacity is required to meet the expected increase in demand for mobile broadband data over the next 10 years [1][2].

In this case the benefits to society include additional consumer surplus¹³ that is generated from increased data consumption as well as increased producer surplus¹⁴ generated from providing the additional data capacity at lower cost than it would otherwise have been provided, even if those benefits are not passed on to consumers. Both these benefits can be calculated as a monetary sum. Therefore,

¹³ Consumer welfare or surplus generated when there is a difference between the price that consumers pay for something compared to the price they would have been willing to pay. This could either be generated due to 1) a reduction in the price of a product/service in order to stimulate increased demand (i.e. a move down the demand curve) or due to an increase in demand meaning that a consumer's willingness to pay increases and more consumers will buy the product/service at the current pricing level (i.e. the demand curve itself moves).

¹⁴ Producer surplus is the difference between the amount that is charged for the product/service compared to the cost of providing the service i.e. it can be thought of as the producer's profit.

in terms of benefits the key stakeholders considered within CBA are the MNOs and the consumers. It is assumed that any potential increase in the sale of handsets as the result of liberalisation is negligible compared to the benefits to MNOs and consumers.

Figure 4-1 depicts the benefits that could be generated were usage of the additional spectrum to enable the relaxation of a data capacity constraint from Q1 to Q2 assuming a static demand curve (i.e. increased demand can only be generated by reducing the price).

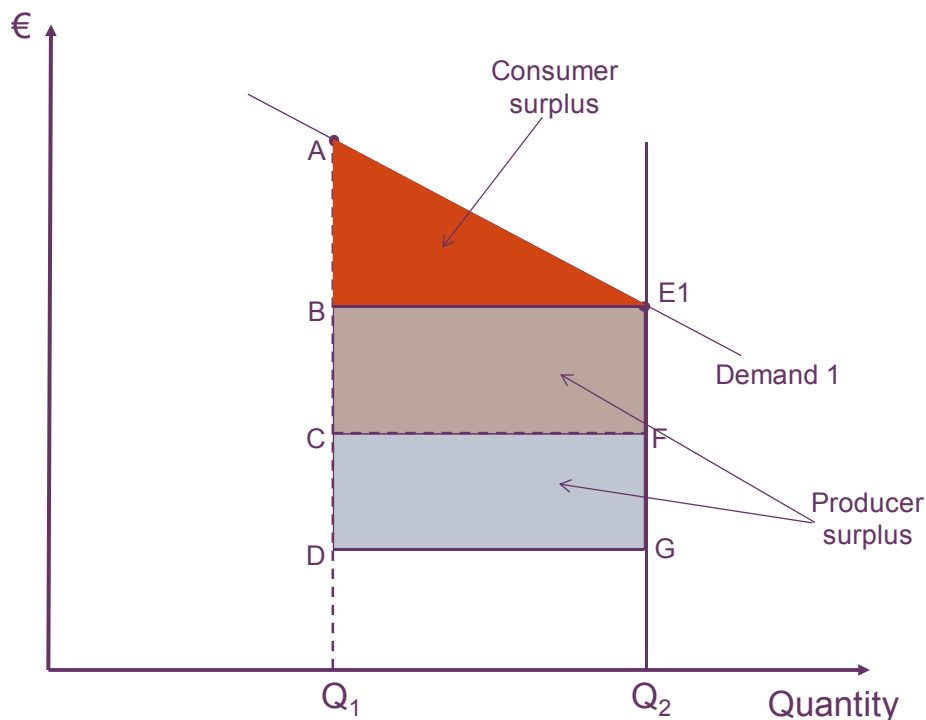


Figure 4-1: Illustration of calculation of socio-economic benefits due to increase capacity

In Figure 4-1 the current service price/demand equilibrium point is at A at the current capacity constraint Q1. As the price is reduced below A the demand increases from Q1 to the new capacity constraint at Q2. The increase in consumer surplus due to the reduction in price and increase in demand is depicted by triangle ABE1. The extent of that increase in consumer surplus is dependent on the extent of the increase in demand (Q1-Q2) and the elasticity of demand (the slope of the demand curve). The more elastic the demand curve (ie, the more price sensitive customers are), the lower the increase in consumer surplus for any given increase in demand.

The producer surplus is simply calculated as the additional revenue generated from increased sales (of mobile broadband data services) due to the increase of data capacity minus the cost of realising the additional capacity:

Producer surplus =

Increase in revenue due to additional capacity =

*(increase in data capacity per unit – cost of increased data capacity per unit) * unit price of data*

Figure 4-2: Calculating producer surplus from increase in revenue

Figure 4-1 above depicts three different cost scenarios.

- If the cost of deploying services (per unit quantity) using this spectrum is at the level shown by BE1, there would be no increase in producer surplus - all the additional benefit would be derived by consumers.
- If the unit costs were CF, producers would benefit from increased producer surplus (or profit) equivalent to rectangle BE1FC. As the capacity constraint of Q2 means that a price reduction below E1 would not increase demand, this additional benefit would not be passed onto consumers, but would be retained by suppliers.
- If unit costs were lower still, at DG, the additional producer surplus would be CFGD. Again, this would be retained by producers and not passed onto consumers.

In order to determine the extent of societal benefits, it is therefore necessary to consider the extent of the increase in demand that could be satisfied, as well as the costs of fulfilling that demand.

4.2.3 Considering the impact of changing demand and capacity with time

A further issue to be incorporated into the analysis is the timescale of when any benefits may be generated. This is relevant as future benefits (and costs) not only have to be discounted to today's values through use of an appropriate discount rate, there is also an interaction between the level of demand, expected growth in demand, and any increase in consumer surplus.

This is illustrated in the following series of four figures. The first three show the increase in capacity from Q1 to Q2, relative to the level of demand in three different years (i.e. as demand increases in time the willingness to pay for data will increase and more people will buy data at a given price and hence data consumption will increase). The fourth figure then shows how the additional consumer welfare is calculated when both the demand and capacity increase within a year. The illustrations assume that the price for data remains constant year on year and that as demand increases more data will be sold at the set price.

In Figure 4-3, the current price/demand equilibrium point is at A along demand curve D1 and therefore the demand is less than the current capacity constraint Q1. Therefore an increase in capacity from Q1 to Q2 would not influence the volume of data sold and hence there would be resulting consumer or producer surplus.

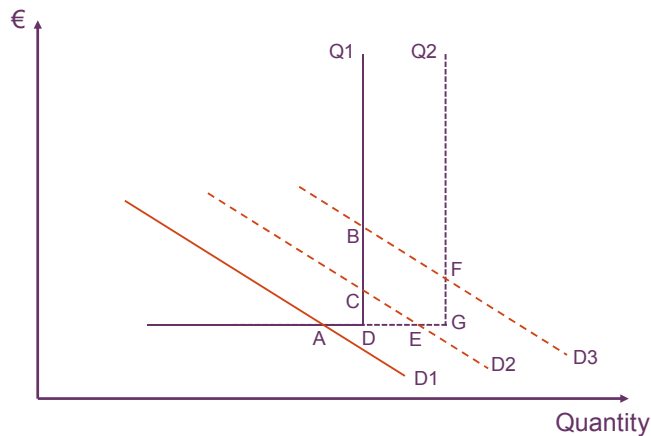


Figure 4-3: Year one – demand, capacity and surplus

In Figure 4-4, increased demand has shifted the demand curve to D2. In this situation, consumers would derive additional surplus as the level of data consumption increases to E at the existing price level, but the increase in demand would not be as great as the increase in capacity. The increase in consumer surplus is depicted as triangle CDE.

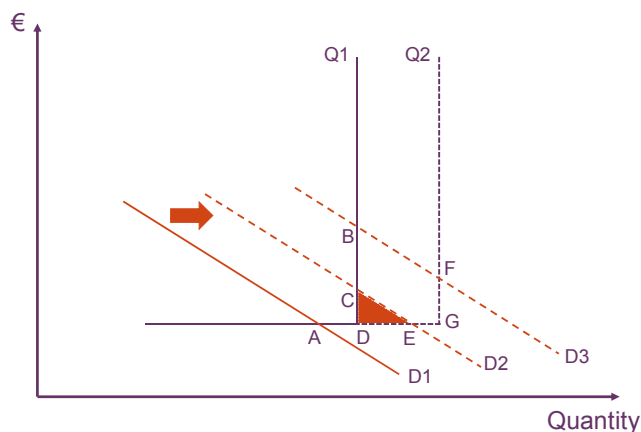


Figure 4-4: Year two – demand, capacity and surplus

In Figure 4-5, demand has increased further, and the capacity constraint has become binding. The additional consumer surplus from relaxing the capacity constraint is the area BFGD.

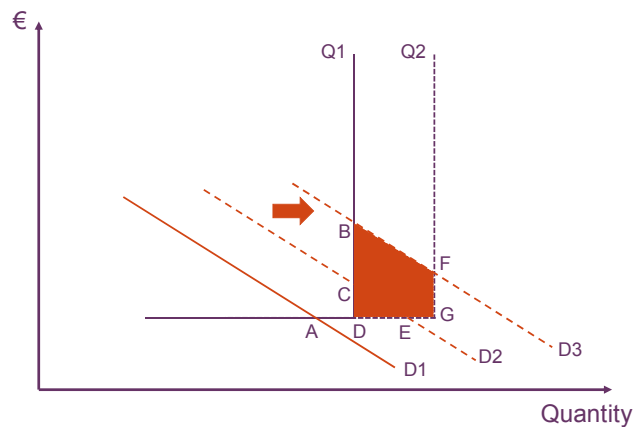


Figure 4-5: Year three – demand, capacity and surplus

Finally, Figure 4-6 shows the increase in consumer surplus that is generated when both the demand and capacity increases within a year. Following on from the figures above, in year 4 there is an increase in capacity from Q2 to Q3 as well as increase in demand from D3 to D4. Therefore the additional consumer welfare generated in year 4 (relative to the current capacity constraint Q1) is given by the blue shaded polygon HIJGFB

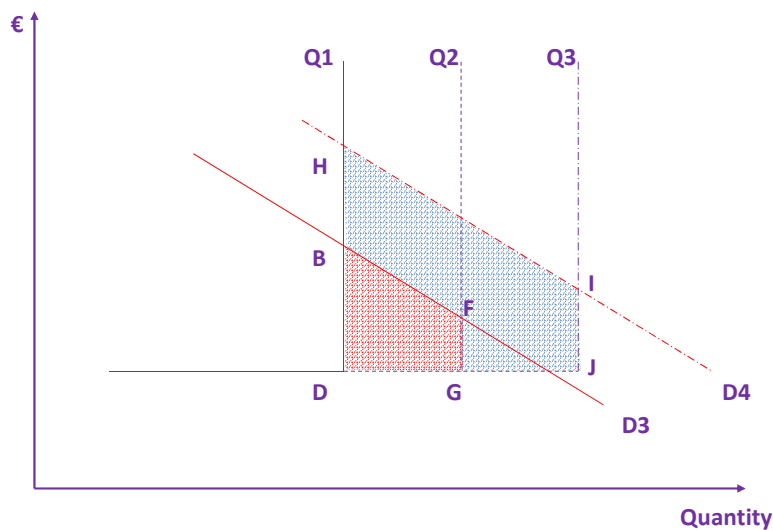


Figure 4-6: Year four - demand and capacity both increase

4.2.4 General approach

MNOs currently have licences for different frequency bands and use different technologies to provide mobile broadband services and voice. As demand for these services grows the MNOs will meet the demand through use of spare capacity within existing spectrum, through the allocation of new spectrum and the implementation of new technologies.

Each of the scenarios identified in section 3.4 for analysis would provide the MNOs with additional capacity to meet increased demand for specific types of data applications (e.g. unicast, multicast, broadcast). The amount of additional capacity

made available over time would depend on the implementation plans of MNOs, the availability of suitable handsets and the impact of any policy implementation.

The CBA itself is conducted from the point of view of a single MNO who is also assumed to be an infrastructure owner. The CBA makes assumptions about the number of MNO subscribers (i.e. it is a configurable input parameter), the number of MNOs in a given country and the total amount of spectrum available for that country. Taking into account the demand for the capacity, the price/demand equilibrium point and price elasticity the consumer surplus and producer surplus are then calculated as described in section 4.2.2 and 4.2.3. The additional producer and consumer surplus figures realised in each year are calculated year-on-year and added to give a monetary net value for each year. Note that the cost figures are already considered within the producer surplus and hence are not subtracted again to give a net value in each year. The figures for each year are then discounted and the results of the CBA are expressed as a discounted cash flow, using the following indicators:

- Net Present Value of the scenario: It is assumed that the scenario is economically viable from the point of view of those stakeholders included in the analysis and taken as a whole, if the net present value indicator is positive.
- Benefit/cost ratio (B/C): The B/C indicator is established as a relationship of the discounted benefits to the sum of discounted costs generated during the entire time horizon. The scenario will be recognised as economically beneficial if the B/C indicator amounts to more than 1.
- Break even period (BEP): Time required by the net cash flow of a project to offset the scenario cost or investment.

The above indicators have been calculated based on the total capacity in Mega Bytes (MB) achieved in each scenario compared to the demand in MB and the cost of achieving the incremental increase in capacity.

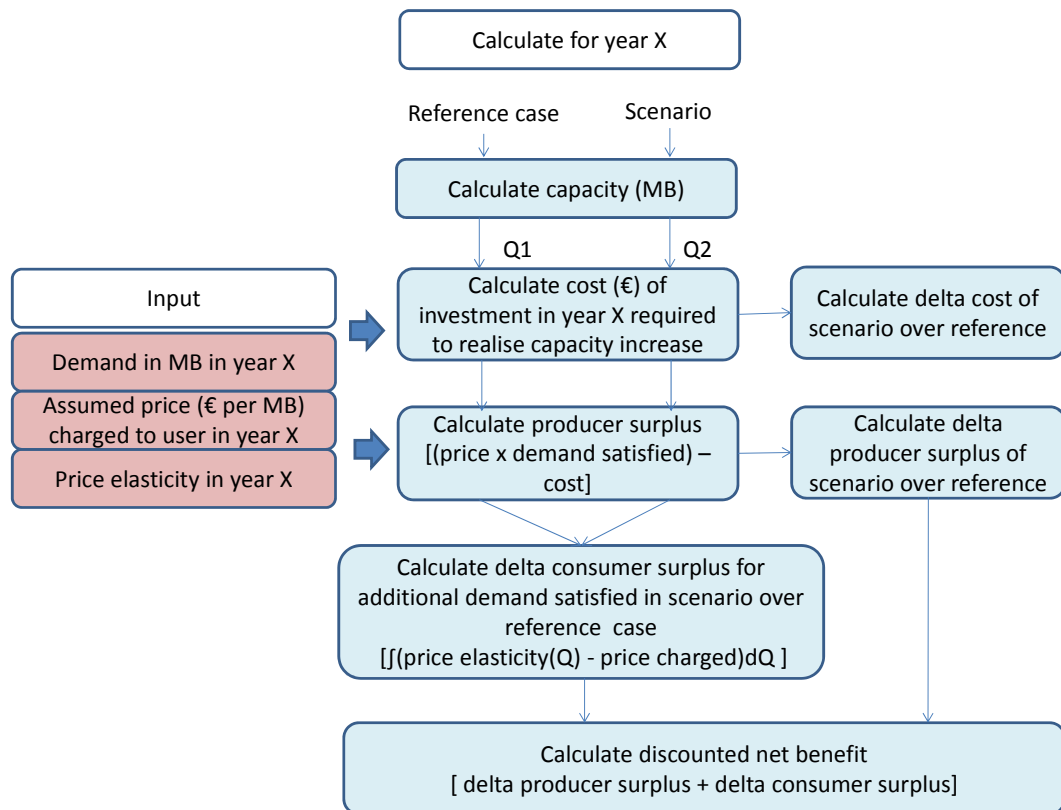


Figure 4-7: Overview of CBA approach

The reference baseline case assumes that the MNOs will meet any increase in demand through existing capacity, migration (re-farming) from one technology to a more efficient one in the same band (in the first instance it is assumed that MNOs will migrate towards LTE), and allocation of new licences under the existing licensing regime. The reference case also assumes that the TDD bands are not extensively used (or at least not within the timescale of the analysis)¹⁶. The bands and technologies highlighted in green in Table 4-1 were therefore considered when calculating the capacity associated with the reference case. The bands and technologies highlighted in yellow were additionally considered when calculating the capacity for each of the scenarios.

Frequency Band	GSM	UMTS	LTE
800 MHz (FDD)			
900 MHz (FDD)		See footnote ¹⁵	
1800 MHz (FDD)		See footnote ¹⁵	
2100 MHz (FDD)			
2100 MHz (TDD)		See footnote ¹⁶	
2600 MHz (FDD)			
2600 MHz (TDD)			

Table 4-1: Bands and technologies available to MNOs

It is clear, even from the table above, that the additional capacity provided through liberalisation of the 2 GHz bands, represents only a small subset of the overall spectrum or capacity available to an operator.

4.2.5 Calculating capacity

The model which has been used to assess the impact of the different scenarios, first models the performance of a representative network in the baseline scenario and then modifies the network to determine the difference in the resulting capacity and cost in the other scenarios.

In order to make the model sufficiently flexible to be able to examine how the impacts change in different European Member States, it takes a number of inputs which are then used to assess capacity. These inputs are detailed in the table below.

¹⁵ The model allows migration from GSM to UMTS to LTE in the 900 MHz and 1800 MHz bands. It is feasible that operators may forego the interim step and migrate directly from GSM to LTE.

¹⁶ In the reference case it is assumed that a small amount of use would take place in the “Do Nothing” reference case based on a small amount of use of IMB and the small TDD networks already implemented in a few Eastern European countries (eg Czech Republic, Slovakia, and Romania). However, major use of the band would only take place following liberalisation and the use of LTE.

Input	Notes
Amount of spectrum in each available band	<p>This can be set to represent any particular operator in any given country. For the purposes of the baseline scenario, it has been assumed that there are [n] operators and that every band is available (or will become so) over the period of the model such that the operator in question has access to:</p> <p>2 x 30/[n] MHz in the 800 MHz band 2 x 35/[n] MHz in the 900 MHz band 2 x 75/[n] MHz in the 1800 MHz band 2 x 60/[n] MHz in the 2100 MHz FDD band 15/[n] + 20/[n] MHz in the 2100 MHz TDD bands 2 x 70/[n] MHz in the 2600 MHz FDD band 50/[n] MHz in the 2600 MHz TDD band</p>
Use of different technologies.	<p>It is assumed that, for those bands which can support multiple technologies (e.g. 900 MHz), over a period of time, some spectrum is re-farmed from the existing technology to a (newer) alternative. Roll-out of new technologies does not occur until sufficient spectrum has been released to enable it. In newer bands (e.g. 2600 MHz), a roll-out of technology over time is assumed. The speed and timing of roll-out can be varied.</p>
Number of cell sites deployed	<p>The total number of cell sites used by an operator is broken down into Femto, Pico and Micro/Macro cells. The overall number of sites is assumed to grow over the period of the model. It is assumed that older technologies (e.g. GSM 900/GSM 1800) are installed on the majority of sites and that these sites are re-used for newer technology as it is rolled out rather than additional new sites being developed.</p>
Spectrum efficiency of different technologies	<p>In order to assess the capacity which the network can produce, the spectrum efficiency of each technology (in Bits/sec/Hz) is required. This is based on the following averages:</p> <p>0.17 Bits/sec/Hz/cell for GSM [8] 0.51 Bits/sec/Hz/cell for UMTS 1.28 Bits/sec/Hz/cell for LTE [9]</p>
Network utilisation	<p>The model calculates the total network capacity. However the MNO infrastructures are built to meet the peaks in demand; therefore not every cell will be used to its full capacity, nor will it be fully utilised every hour of the day. To reflect this, and based on discussions with MNOs, a factor of 20% has been applied to the total network capacity generated to represent the capacity actually available for consumption as opposed to the theoretical maximum capacity generated assuming a constant 24/7 demand. However, we also look at the impact of using lower (10%) and higher (30%) utilisations in the sensitivity analysis.</p>
Type of capacity	<p>Most technologies deliver unicast data connectivity; however one scenario considers the use of broadcast (IMB/EMBS) technology which delivers multicast capability.</p>
Handset capability	<p>Whilst networks can be developed using specific technologies, the capacity which that network generates cannot be used until it can be consumed in user terminals (e.g. handsets). As such, account is taken of the proportion of handsets in any given year</p>

Input	Notes
	which are capable of using the available network technologies. Handset capabilities are considered on a per technology basis only i.e. they are assumed to support all frequencies considered in the CBA. The new technologies will be included in handsets by the manufacturers as part of their overall product development roadmap.

Table 4-2: Variable inputs to the cost and capacity model

Total network capacity is therefore calculated as the sum of the capacity produced by each cell, of each technology type, in each band, as modified by the utilisation factor.

No specific account has been taken of the utilisation of the network for the delivery of voice calls. Where mobile penetration has reached 100% (as it has over most of Europe), the load on the network due to voice calls will be relatively constant (in data bandwidth terms) over the period of the model. This represents a base load on the network which will become a smaller proportion of overall network traffic as data use grows. Whilst the inclusion of voice traffic would be important for calculating differentials in pricing, it is reasonable to assume that any growth in network capacity will be used for delivering enhanced data connectivity and not additional voice capacity and given that the model is comparing the network year-on-year, voice can safely be treated as a fixed data load.

Additional key assumptions that were made in calculating network capacity are as follows:

- No additional spectrum becomes available to MNOs during the period of the analysis, outside of those already considered in this study¹⁷.
- The UMTS TDD bands will eventually be used in the “Do Nothing” reference case but only after all other options for capacity increase with FDD bands has been exhausted. It is therefore assumed that full use of the UMTS TDD bands would only happen at a much later date outside of the time duration of the CBA. Within the time duration of the CBA only limited use will be made of the UMTS TDD bands in the “Do Nothing” case based on some IMB implementations and small TDD networks currently implemented in Eastern Europe.
- The network capacity is calculated individually for femto cells (Group I), pico cells (Group II) and macro/micro cells (Group III). The current cell site populations are:
 - Femto cells: 0
 - Pico cells: 3,000
 - Macro/micro cells: 7,000
- The number of both pico and macro/micro cells increase by 2% each year.

¹⁷ Whilst this is unlikely to represent actuality, additional spectrum will impact equally across all scenarios. Though this may change the absolute value of the results, it will not impact the relative assessment of options.

- Femto cells will only exhibit a significant uptake within the context of Scenario 2 (low power TDD services) and in this scenario they will increase to 1,085,856 by 2021 based on a market study carried out by the femto forum.
- A separate network utilisation figure of 2% was applied to the use of femto cells in scenario 2. This value was chosen to be 1/10th of the utilisation of the rest of the network to reflect the fact that the amount of time a femto cell was likely to be in use during a day is less than macro or micro cells.
- For scenario 3 it was assumed that on average 4 users in each FDD cell would be using common content that could then be delivered via the 2 GHz TDD cell. Therefore, each 1 MB of capacity provided by the 2 GHz TDD cells results in a capacity increase equivalent to 4 MB across the network.

Figure 4-8 below, illustrates an example output of the network capacity model. The total capacity is shown per cell type (group I being macro/micro cells, group II being pico cells and group III being femto cells which are not widely used in this particular example).

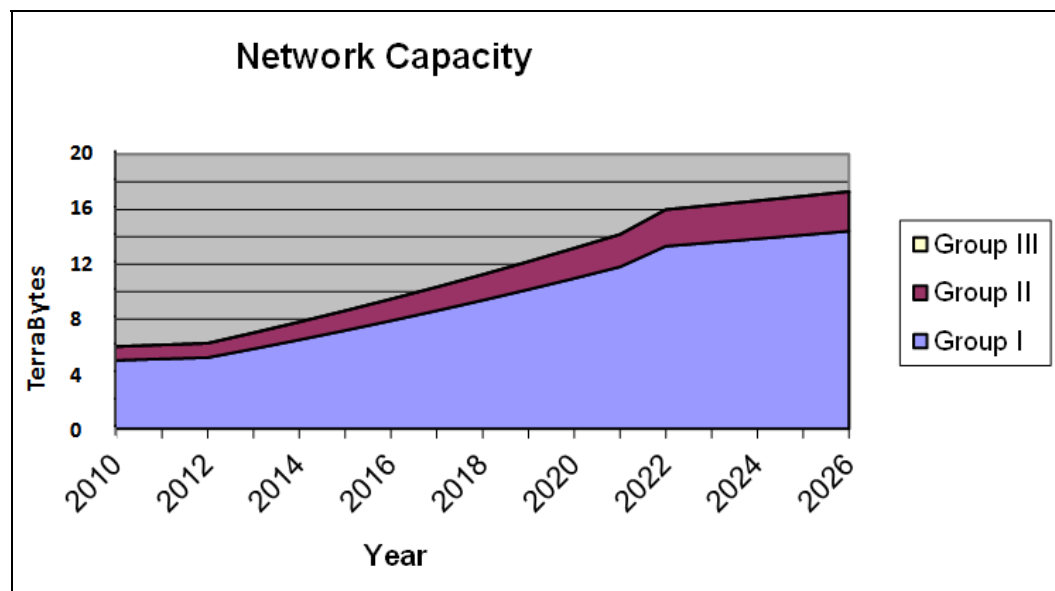


Figure 4-8: Example network capacity calculation

4.2.6 Calculating costs

The cost of infrastructure and equipment required to enable increases in MNO network capacity available in any given year was calculated taking into account the following inputs:

- Cell site costs:
 - Number of new cell sites
 - Number of sites that will be upgraded and the new technology that will be implemented
- Backhaul costs:

- Cost to increase backhaul capacity where current cell site thresholds are exceeded¹⁸

Additional key assumptions that were made in calculating costs are as follows:

- The main sources of cost are in the implementation of new cell sites or upgrading equipment at existing cell sites, and backhaul. All other costs (such as base station controllers, mobile switching centres, and so forth) are considered an order of magnitude lower given the smaller number of upgrades and changes that will be required to those network elements than to cell-sites and backhaul. In addition it is assumed that operating costs remain the same in the baseline and all other scenarios and can therefore be ignored.
- Femto cells are assumed to utilise existing backhaul infrastructure (e.g. local ADSL connections) and therefore backhaul costs are only applied to pico and macro/micro cells.
- IMB and EMBS will use satellite links for backhaul rather than fixed point-to-point links. Satellite links are a cost efficient way of delivering common content to multiple cell site locations.
- Although there is a cost associated with the production and distribution of handsets with new capabilities (i.e. supporting new technologies or with new filters) it is assumed that these costs are largely the same in both the reference case and the scenario under investigation. These costs can therefore be ignored when considering the difference in cost between the reference case and any particular scenario. For example, based on the feedback received from equipment manufacturers during the survey it is assumed that new handsets entering the market will include multi-mode, multi-band chipsets that are UMTS FDD, FD-LTE and TD-LTE capable; the costs of implementing RF components in a handset is minimal⁷ and that timing of any policy decision will not greatly impact the market penetration of new devices.
- No costs have been included for any equipment external to the handset required to utilise a frequency/technology/service. It is assumed that external equipment is only required in the case of IMB where the UMTS TDD technology is implemented in a USB dongle which is attached to a handset. However, due to the relatively small amount of IMB usage assumed in both the baseline and the other scenarios this additional cost is assumed to be marginal and not significant to the overall outcome.
- Any costs associated with realising the pairing of spectrum (for scenario 4) are not taken into account but could potentially be significant and would need to be considered on a case by case basis.
- Within each scenario the MNOs will use the available frequency bands in the same way (i.e. the use of the bands is harmonised; no standalone decisions will be made; all operators will assume the same option collectively). Therefore any additional costs associated with coordinating use of the bands in the case of non-harmonised use are not considered.
- The cost figures are assumed constant for the duration of the analysis period and are based on current costs.

¹⁸ Note that it is assumed that femto cells require no (network provided) backhaul as they are connected to the user's own Internet connection.

Further detailed cost assumptions are contained in annex E.

4.2.7 Calculating demand

The demand for mobile broadband data was derived from predictions made in various widely recognised industry reports [1] [2]. In particular the current global demand for mobile data is 240,000 Terabytes per month according to Cisco's 2011 white paper on traffic growth. The paper reports high growth in the immediate term with 150% growth set for this year. The annual growth steadily declines reaching 56% for 2015, its final year of forecast.

In addition the following key assumptions relating to demand were made:

- The demand curve is assumed to represent exogenous demand (i.e. the level of demand if there were no capacity constraints).
- The demand curve assumes demand for data associated with M2M applications as well as user orientated applications and services.
- This forecast trend is extended beyond 2015 (based on professional judgement) with a continuing decline in annual growth reaching a steady continuous 5% growth from 2020 onwards.
- A country specific demand trend is derived from the above global trend on the basis of population. In turn, the specific demand for a single MNO is obtained by dividing by the total number of MNOs in the country assuming each has an equal share of the market.

Different data demand growth predictions were also investigated in the sensitivity analysis.

4.3 Assumptions

This section describes the additional high level assumptions made in the CBA.

CBA Parameter	Assumption	Note
Cash flows	Nominal cash flows	The cash flows used in the CBA are not adjusted for inflation
Time duration of analysis	10 years (2011 to 2021)	The analysis is restricted to 10 years because it is difficult to predict technology and market developments and MNO plans beyond this time frame.
Date of liberalisation (2 GHz bands)	2013	This is the date that liberalisation is assumed to be implemented in the 2 GHz (FDD and TDD bands). (Note that the process of liberalisation may begin before this date.) Any rollout of new technology enabled by liberalisation is assumed to start in the year before the liberalisation but accelerate following liberalisation. The impact of changing the liberalisation date to 2015 and 2017 is also investigated in the sensitivity analysis.
Date of liberalisation (other bands used by MNOs)	2013	This is the date that liberalisation is assumed to be implemented to other (non 2 GHz bands) that are used by MNOs to deliver mobile voice and broadband data services). Any rollout of new technology enabled by liberalisation is assumed to start in the year before the liberalisation but accelerate following liberalisation. This date is applied in the same way in both the reference baseline as well as the scenarios under investigation.
Discount rate (for nominal cash flows)	10%	The discount rate reflects how the cash flows are valued over time and in particular reflects the expected rate of return for an investment from a commercial point of view. Source figures [3][4][5] suggest values ranging from 3.5% for a rate of return to reflect society's value of the benefits, 5% for the opportunity cost of capital (the likely return for an alternative investment of the capital) to 11.5% for a rate of return expected by a commercial organisations in the mobile sector. For investments that are considered risky higher discount figure may also be used. It is noted that these discount rates are for real cash flows and the CBA is conducted for nominal cash flows. These figures are therefore used to provide an indicative range of discount rates. For the purposes of this analysis we have chosen 10% as an appropriate commercial discount rate for the mobile sector but we also look at the impact of changing this to 5% and 15% in the sensitivity analysis.
Price of data	€0.013 per MB	The price the user pays for consuming data is based on research conducted into typical current data price plans offered by operators in Europe, an Ofcom UK market assessment [6] and a report on European data roaming prices [12]. It is assumed that price paid by consumers for the additional capacity is set based on the general demand for mobile broadband data. The

CBA Parameter	Assumption	Note
		research indicated that the current price levels are in the range €0.013 to €0.13 per MB with prices generally falling year on year, although with demand for data expected to increase rapidly in the coming years it is assumed that we are currently approaching a price equilibrium point where the price will stabilise. It is likely that the price of data will continue to change over time and also for different types of services. However, it is difficult to predict this trend within any certainty. Therefore for simplicity of analysis the price has been kept constant at the bottom of the currently established price range but we also look at the impact of increasing this value in the sensitivity analysis.
Price elasticity of demand	-1.0	The price elasticity represents the responsiveness of changes in demand to percentage changes in price (price elasticity = % change in demand / % change in price). The value chosen was taken from the reference literature sources [3][7] that most closely match the scenarios under investigation in this CBA. The value was derived through historical analysis in the mobile market and applying assumptions as to how it would change in the future. Like the unit price of data the actual price elasticity is likely to vary with time and for different types of services. New services may be considered as luxury goods attracting higher prices and higher (magnitude) price elasticities. Therefore for simplicity of analysis the price elasticity has been kept constant but we also look at the impact of the price elasticity increasing to -0.5 or decreasing to -1.5 in the sensitivity analysis. The range of the increase or decrease was set based on the typical range of price elasticities observed during the research.
Country type under analysis	UK - high number of cell sites and subscribers	The UK had the widest range of data (price, number of subscribers, number of operators, number of cell sites, costs) readily available to the project team and therefore was selected as the reference country on which to carry out the initial analysis. However, other European countries (characterised in terms of number of subscribers and cell sites) were also investigated in the sensitivity analysis through additional case studies based on data obtained for Romania, the Netherlands and Slovakia.

Table 4-3: Key CBA input assumptions

4.4 Scenario 1: Macro cells – high power TDD

The CBA results for Scenario 1 are summarised below.

Scenario 1 relative to Baseline		
Economic Benefits		
Cumulative Benefits	Net Present Value (M€)	Net Value (M€)
Consumer welfare	35	54
Producer surplus	82	134
Total	117	188
Additional Indicators		
BEP	2015	
B/C	0.63	
Background Cost Information		
Delta Costs	Net Present Value (M€)	Net Value (M€)
Delta cell site costs	186	300
Delta backhaul costs	1	1
Total	187	301

Table 4-4: Summary of scenario 1 CBA results

Scenario 1 yields an economic benefit of 117M€ NPV over the analysis period. Whilst there is some benefit from consumer welfare to be realised, this is just half the value of the producer surplus generated. The Break Even Point (BEP) is achieved in 2015, two years after liberalisation, with a Benefit-to-Cost (B/C) ratio of 0.63.

The use of the 2 GHz TDD bands for high power TDD has minimal impact on the network achieving just a 7% increase in utilised capacity (see Figure 6-1 in section 6).

As a result only marginal economic benefits are possible with respect to the baseline. The cumulative value of these is illustrated in Figure 4-9 below.

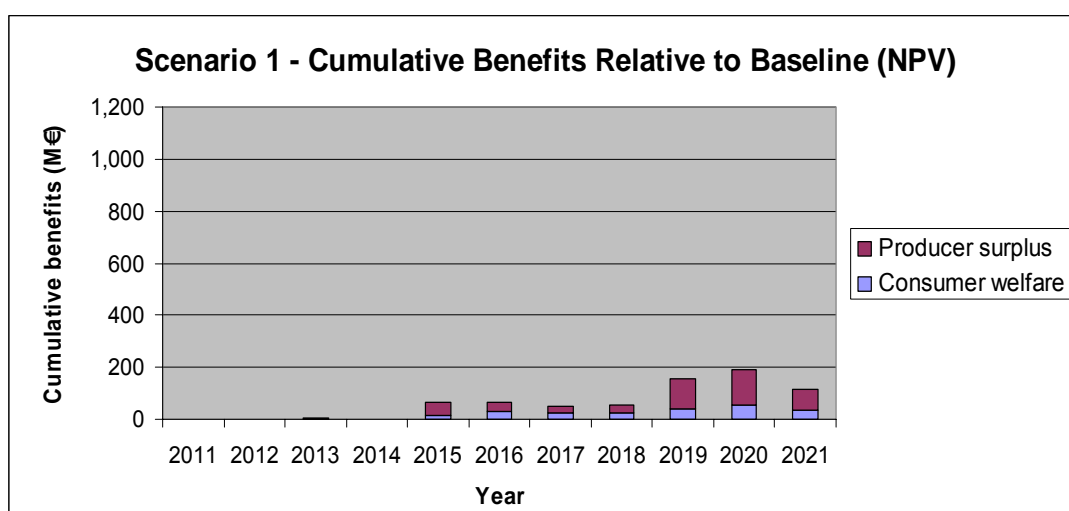


Figure 4-9: Scenario 1 cumulative benefits

Any additional consumer welfare remains low as there is no significant change to the ability of the network to meet a growing demand. The cumulative producer surplus exhibits a slightly undulating trend where a reduction is observed owing to a temporary decrease in capacity when UMTS is phased out and LTE phased in within the band. Continued investment in the rollout of LTE begins to surpass the benefits of the marginal increase in capacity with a second downward trend in cumulative producer surplus observed from 2021 onwards.

4.5 Scenario 2: Femto cells – low power TDD for indoor/home use

The CBA results for Scenario 2 are summarised below.

Scenario 2 relative to Baseline		
Economic Benefits		
Cumulative Benefits	Net Present Value (M€)	Net Value (M€)
Consumer welfare	100	164
Producer surplus	1,033	1,916
Total	1,133	2,080
Additional Indicators		
BEP	2013	
B/C	3.84	
Background Cost Information		
Delta Costs	Net Present Value (M€)	Net Value (M€)
Delta cell site costs	295	488
Delta backhaul costs	1	1
Total	295	489

Table 4-5: Summary of scenario 2 CBA results

Scenario 2 yields significant economic benefits of 1,133M€ NPV over the analysis period. Again producer surplus benefits far exceed those of consumer welfare however both contribute strongly in this scenario. The BEP is achieved in 2013 (the year liberalisation is implemented) with a B/C ratio of 3.84.

The use of the 2 GHz TDD bands for low power TDD femto cells for indoor/home use has a significant impact on the network capacity with a 35% increase in utilised capacity towards the end of the analysis period (see Figure 6-1 in section 6). As a result significant economic benefits are possible with respect to the baseline. The cumulative value of these is illustrated in Figure 4-10 below.

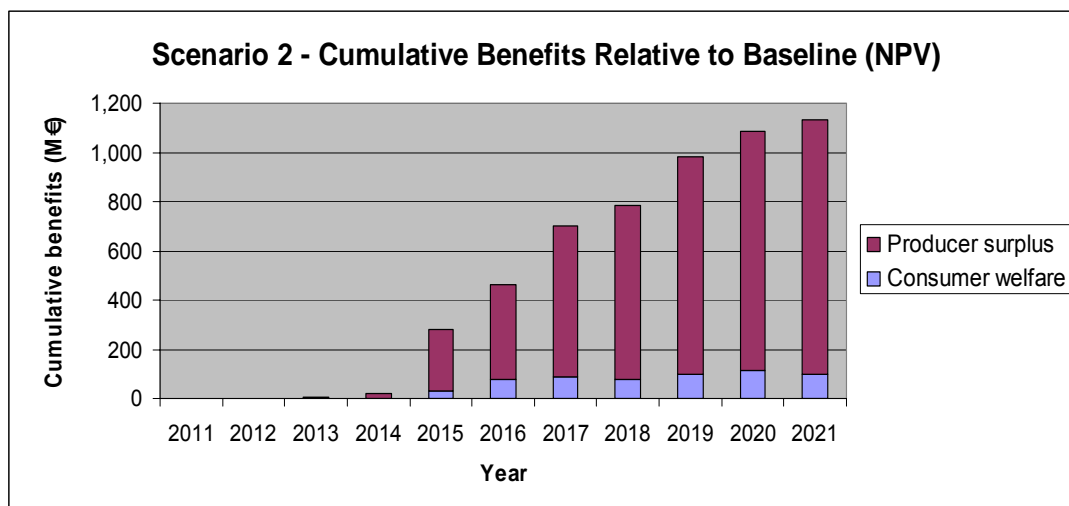


Figure 4-10: Scenario 2 cumulative benefits

Cumulative consumer welfare (relative to the baseline) reaches its peak in 2020 when the greatest difference between demand and capacity is observed. From this point it begins to decrease as demand continues to increase whereas the annual increase in capacity has reached its peak with the number of femto cells reaching its expected maximum population. Again, the marginal decrease in cumulative benefits previous to this are centred on the transitional period where UMTS is phased out and LTE phased in and there is a temporary decrease in capacity.

Producer surplus begins to increase rapidly once the spectrum is liberalised in 2013 and the network capacity grows, in line with the rollout of the femto cells, allowing the operator to meet increasing demand at reduced cost.

4.6 Scenario 3: Downlink only services

The CBA results for Scenario 3 are summarised below.

Scenario 3 relative to Baseline		
Economic Benefits		
Cumulative Benefits	Net Present Value (M€)	Net Value (M€)
Consumer welfare	101	164
Producer surplus	1,037	1,732
Total	1,138	1,896
Additional Indicators		
BEP	2013	
B/C	6.02	
Background Cost Information		
Delta Costs	Net Present Value (M€)	Net Value (M€)
Delta cell site costs	188	302
Delta backhaul costs	1	2
Total	189	304

Table 4-6: Summary of scenario 3 CBA results

Scenario 3 yields significant economic benefits of 1,138M€ NPV over the analysis period. Producer surplus benefits far exceed those of consumer welfare however both again contribute strongly in this scenario. The BEP is achieved immediately with liberalisation in 2013, where capacity savings from the broadcast of common data are realised straight without delay, with a B/C ratio of 6.02.

The use of the 2 GHz TDD bands for downlink only services has significant impact on the utilised network capacity (as illustrated in Figure 6-1 in section 6). An immediate increase in capacity is realised as common content is pushed to users via a downlink only channel. This increase in capacity continues to grow as overall demand increases and more and more common data content is provided in this manner. As a result significant economic benefits are possible with respect to the baseline. The cumulative value of these is illustrated in Figure 4-11 below.

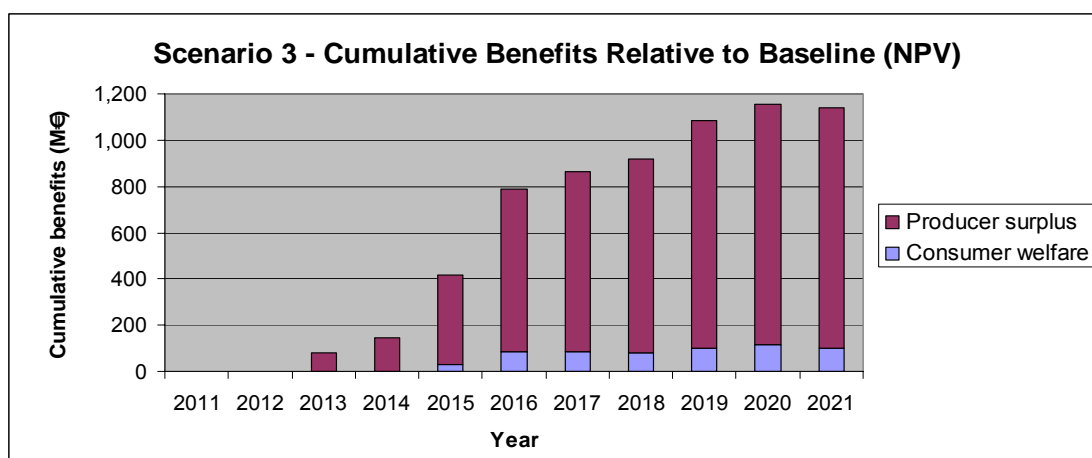


Figure 4-11: Scenario 3 cumulative benefits

The cumulative consumer welfare and producer surplus trends are similar to Scenario 2 albeit marginally higher where the increase in capacity is realised quicker. This is especially true for producer surplus where the allocation of common content to broadcast enables a significant increase in the backhaul costs.

4.7 Scenario 4: FDD services - uplink only in TDD band paired with downlink in another band

The CBA results for Scenario 4 are summarised below.

Scenario 4 relative to Baseline		
Economic Benefits		
Cumulative Benefits	Net Present Value (M€)	Net Value (M€)
Consumer welfare	61	94
Producer surplus	281	443
Total	341	536
Additional Indicators		
BEP	2013	
B/C	1.82	
Background Cost Information		
Delta Costs	Net Present Value (M€)	Net Value (M€)
Delta cell site costs	186	300
Delta backhaul costs	1	2
Total	187	302

Table 4-7: Summary of scenario 4 CBA results

Scenario 4 yields an economic benefit of 341M€ NPV over the analysis period. Whilst there is some benefit from consumer welfare to be realised, this is just a quarter of the producer surplus. The BEP is achieved immediately in 2013, where the capacity savings of pairing are realised without delay, with a B/C ratio of 1.82.

Nonetheless, the use of the 2 GHz TDD bands for uplink as part of paired FDD bands only has minimal impact on the utilised network capacity (as illustrated in Figure 6-1 in section 6). As a result only marginal economic benefits are possible with respect to the baseline. The cumulative value of these is illustrated in Figure 4-12 below.

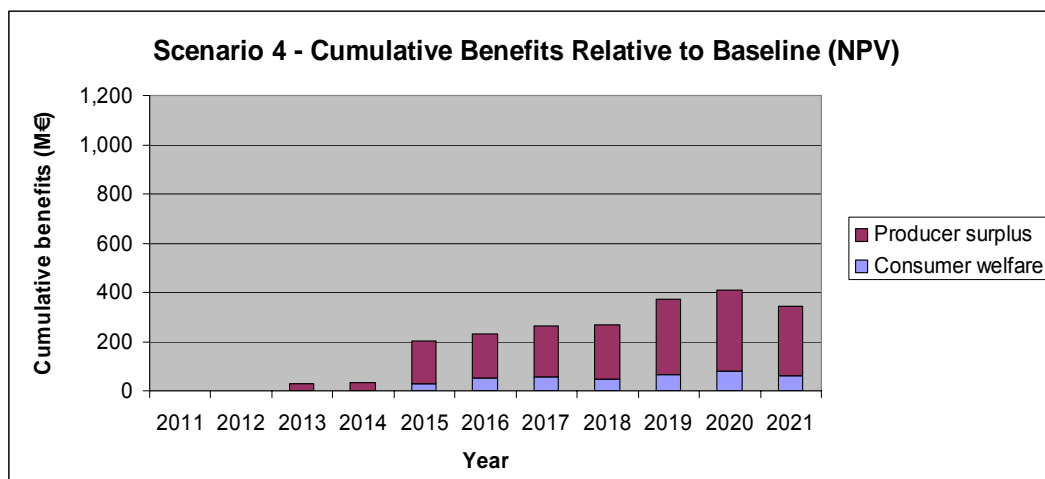


Figure 4-12: Scenario 4 cumulative benefits

As to be expected, both the cumulative consumer welfare and producer surplus exhibit similar behaviour to that of Scenario 1. The relative increase is double that of Scenario 1 and therefore so too are the accumulated benefits.

4.8 Comparison of scenario NPVs

Based on the above results Figure 4-13 below shows the relative economic benefits of each of the scenarios. The figure clearly shows that scenario 2 and 3 have greater economic benefits compared to scenario 1 and 4.

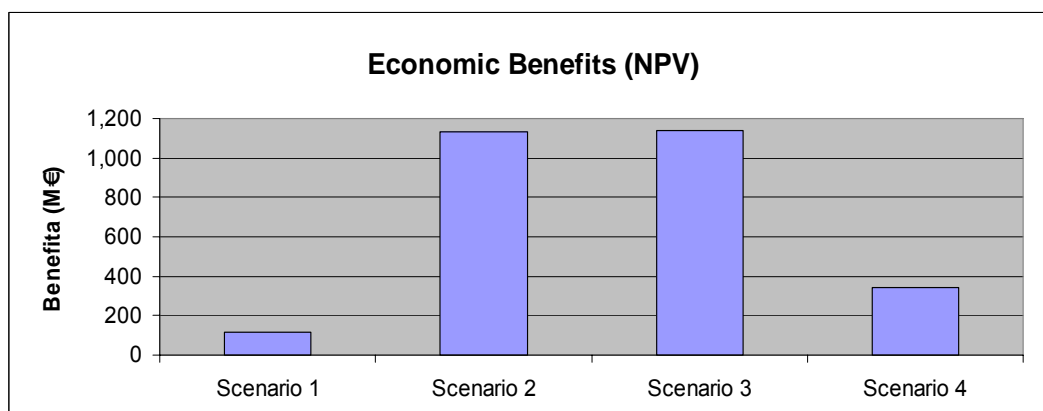


Figure 4-13: Comparison of scenario NPV benefits (relative to baseline)

5 Sensitivity analysis

5.1 Introduction

A sensitivity analysis was conducted to investigate the impact that changes in assumed values for key CBA inputs have on the results presented in sections 4.4 through to 4.7. This is particularly important for inputs where there is no single clearly accepted value. The sensitivity analysis is used to identify which of the assumptions have the greatest impact on the results. In addition the analysis is also used to determine the ranges for the input values under which the results of the CBA analysis still remain true.

The results of the sensitivity analysis are presented below where the following parameters have been investigated:

- discount rate;
- network utilisation;
- unit price of data ;
- timing of liberalisation in the 2 GHz band;
- price elasticity;
- data demand;
- infrastructure costs;
- number of operators;
- number of subscribers per cell using common content;
- different country case studies (i.e. number of cell sites and subscribers).

5.2 Discount rate

The discount rate (real terms) used in the CBA above was assumed to be 10%. The figures below illustrate the impact of using a discount rate of 5% and 15% respectively.

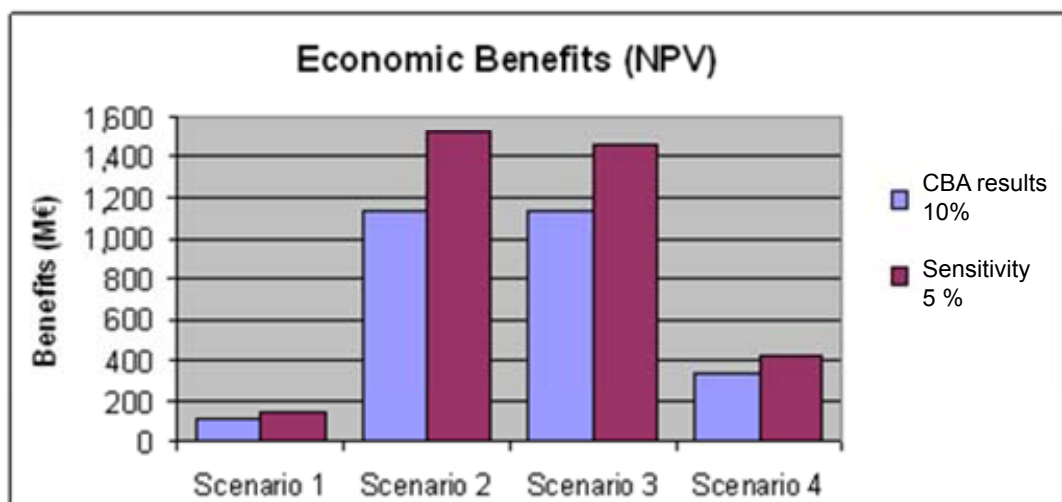


Figure 5-1: 5% discount rate

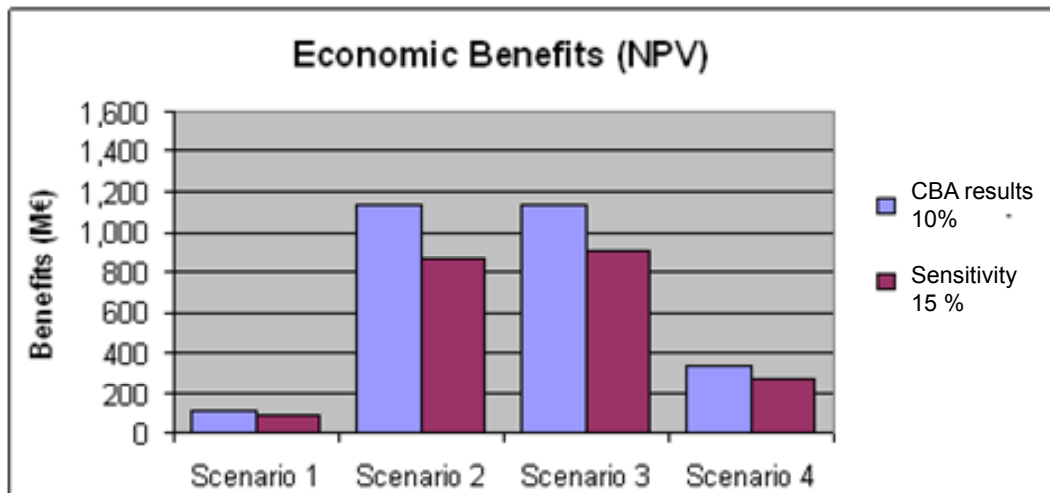


Figure 5-2: 15% discount rate

It is noted that the discount rate effectively scales the absolute NPV benefits for each scenario. A lower discount rate increases the NPV as the benefits that are seen to accrue in the later years within each scenario have a greater contribution to the resulting NPV. However, it is also worth noting that changing the NPV can also change whether scenario 2 or 3 results in the largest economic benefits.

5.3 Network utilisation

The network utilisation used in the CBA above was assumed to be 20%. The figures below illustrate the impact of using utilisation values of 10% and 30% respectively¹⁹.

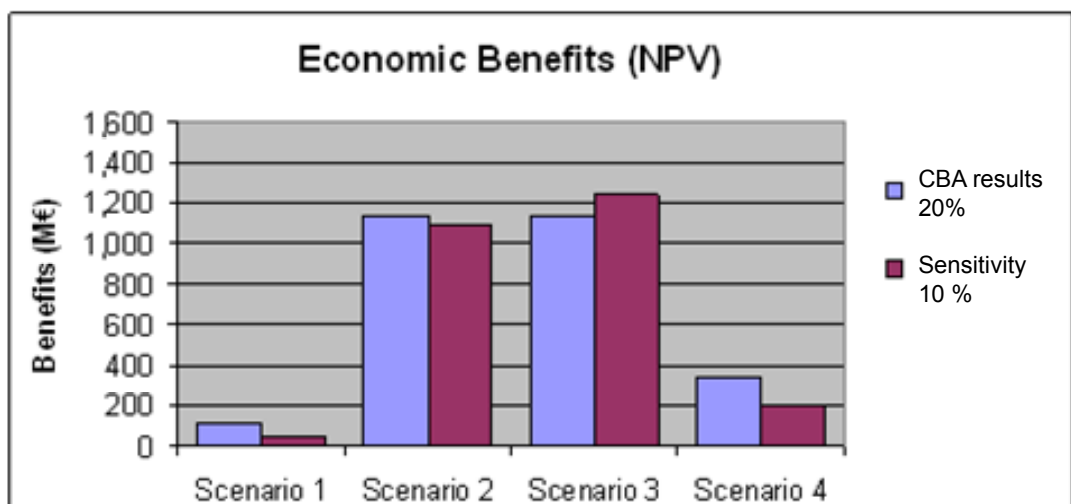


Figure 5-3: 10% network utilisation

¹⁹ Note, that in scenario 2 the femto cell utilisation was also varied. It was assumed that the femto cell utilisation was 1/10th that of the utilisation of the wide area network.

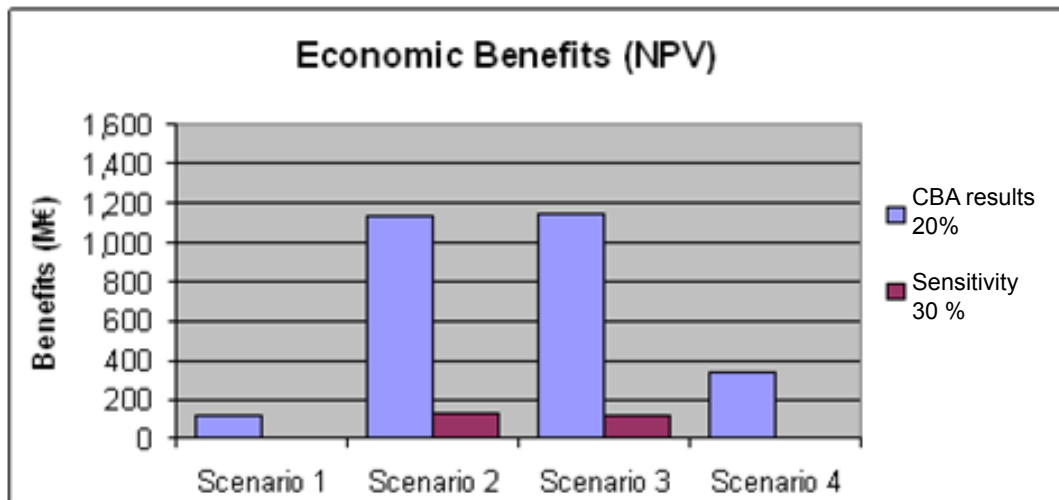


Figure 5-4: 30% network utilisation

The results show that network utilisation can have a significant impact on the CBA results as it plays a key role in determining whether the economic benefits are assessed within a capacity constrained or demand constrained environment. An increase in utilisation means that more of the increased demand can be met with within the existing MNO infrastructure and other frequency bands i.e. the environment becomes demand constrained. There is therefore little benefit to be gained from increasing the capacity further using the 2 GHz TDD bands. A reduction in utilisation results in an environment which is increasingly capacity constrained and where less additional capacity (and therefore benefit) is being realised for a given cost.

It is noted that scenarios 2 and 3 remain the scenarios with the greatest economic benefits. However, it also noted that scenario 3 is the only scenario whose NPV increases as the network utilisation is reduced to 10%. Scenario 3 is a cost efficient way of realising increases in capacity on the assumption that there is common content required by users that can be delivered via downlink only services.

5.4 Unit data price

The data price used in the CBA above was assumed to be 0.013€ per MB. The reference data suggested typical current data prices were in the range 0.013€ to 0.13€. The figure below illustrates the impact of using 0.13€ per MB. This also illustrates the potential additional benefits that might arise if use of the 2 GHz TDD bands enabled new types of highly desirable services and applications.

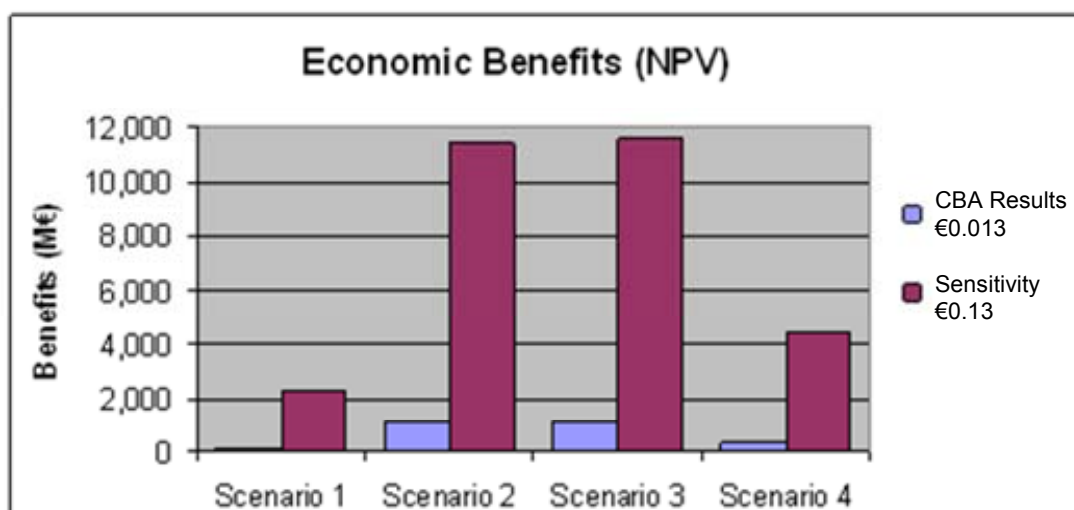


Figure 5-5: €0.13/MB unit data price

As expected the unit data price just scales the economic benefits. The data price is fundamental in setting the absolute value of the resulting economic benefits as it is a central part of the calculation of the consumer surplus as well as the additional revenue generated by the MNO from sale of the additional capacity.

5.5 Timing of implementation of liberalisation in the 2 GHz band

The implementation of liberalisation in the CBA above was assumed to be 2013. The figures below illustrate the impact of implementing²⁰ liberalisation in 2015 and 2017 respectively.

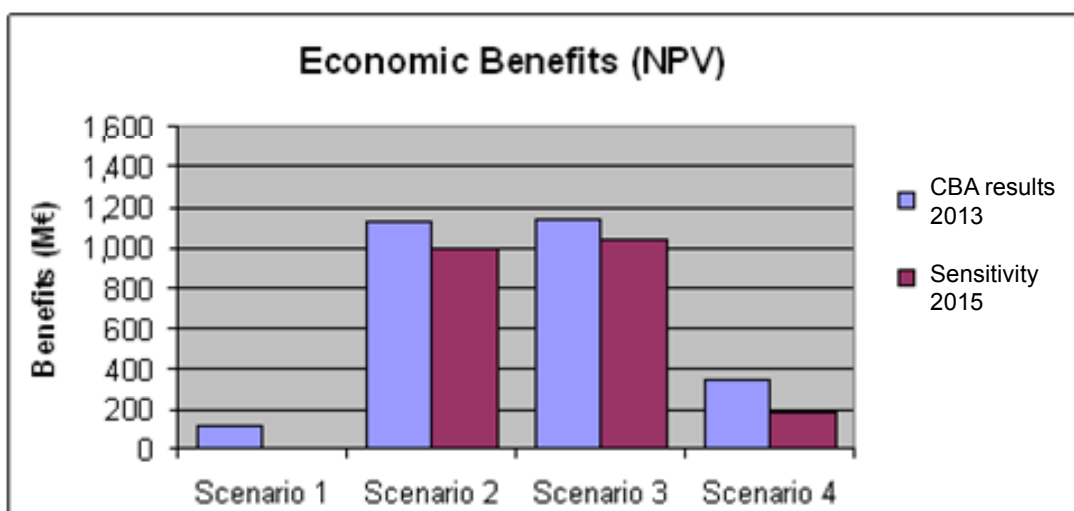


Figure 5-6: Liberalisation implemented in 2015

²⁰ Note that the effects of liberalisation may begin before the implementation date, if it is known in advance that liberalisation will take place.

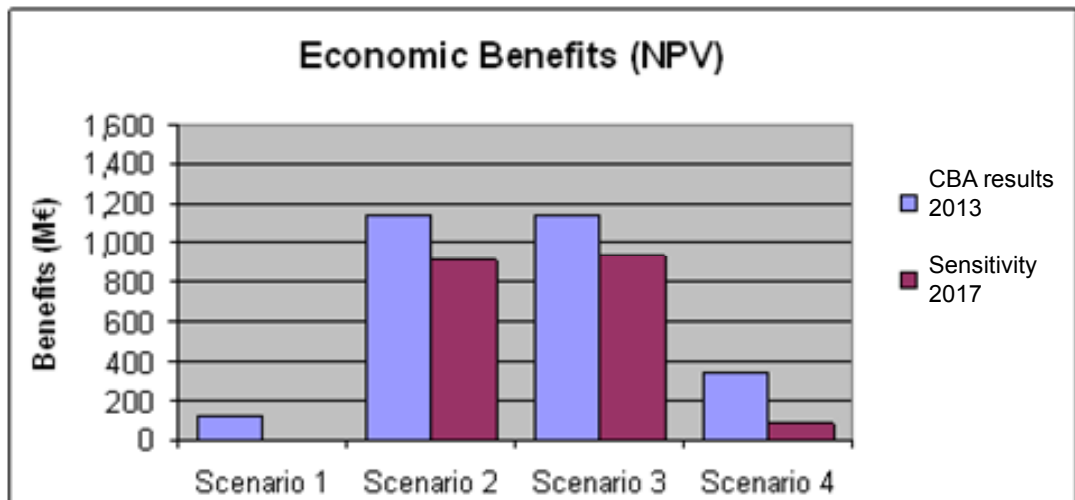


Figure 5-7: Liberalisation implemented in 2017

A later decision to liberalise will reduce the economic benefits generated by approximately 100M€ for each year of delay. It does not however affect the relative value between scenarios. The optimum liberalisation date is closely linked with the date of any transition between a demand constrained and capacity constrained environment, and is therefore closely linked to the predicted increase in demand.

5.6 Price elasticity

The price elasticity used in the CBA above was assumed to be constant at -1.0 throughout the analysis period. The figures below illustrate the impact of using constant price elasticities of -0.5 and -1.5 respectively.

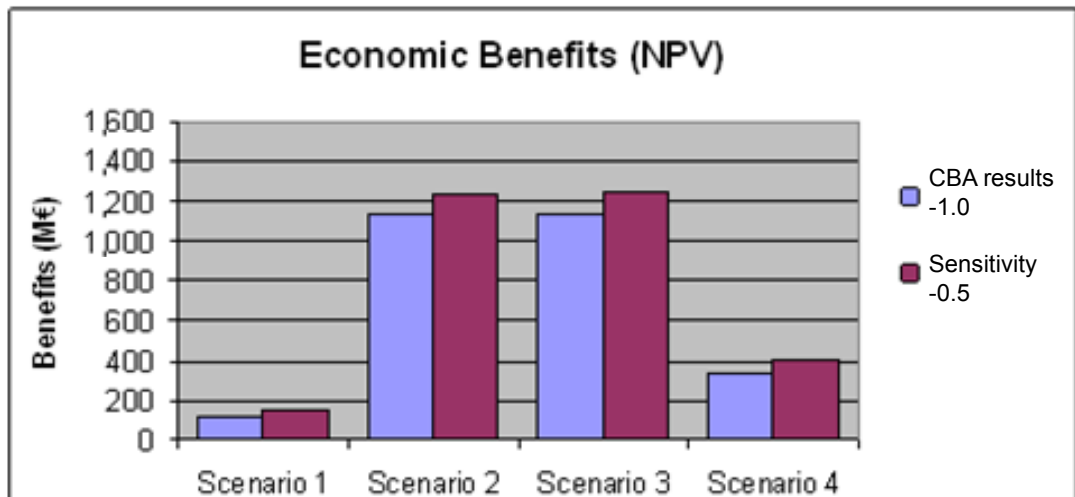


Figure 5-8: -0.5 price elasticity

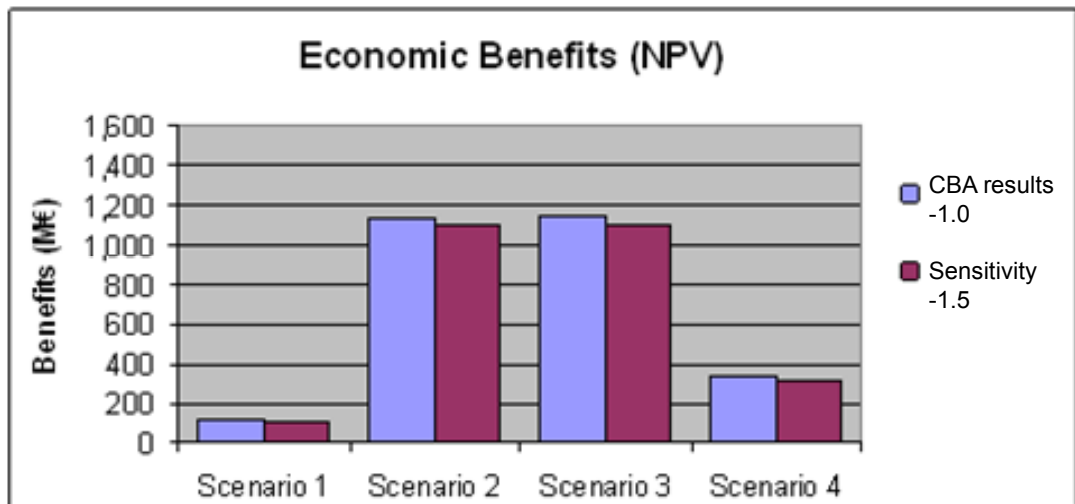


Figure 5-9: -1.5 price elasticity

As expected the results scale according to the price elasticity used. A decrease in the assumed elasticity results in increased economic benefits, and vice-versa.

5.7 Data demand

The data demand used in the CBA above was assumed to follow the Cisco industry forecasting (extended within the context of the analysis period based upon professional judgement) with a 150% annual growth in 2011 gradually reducing to 5% in 2021.

The figures below illustrate the impact of changing the growth predictions to:

- 120% annual growth in 2011 gradually reducing to 4% in 2021;
- 180% annual growth in 2011 gradually reducing to 6% in 2021.

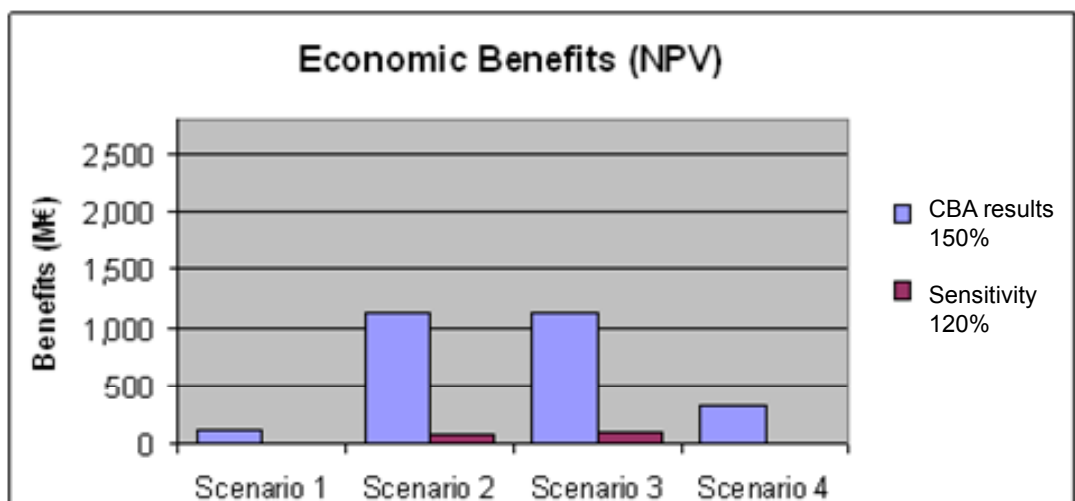


Figure 5-10: 120% annual growth of data demand

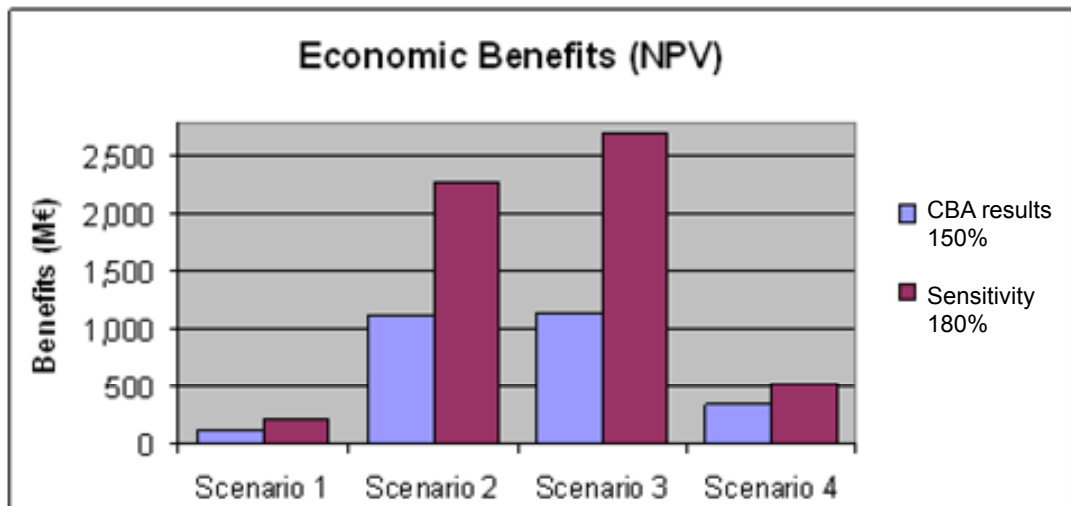


Figure 5-11: 180% annual growth of data demand

The data demand is a key assumption which plays an important role on determining whether the economic benefits are assessed within the context of a capacity constrained or demand constrained environment. It has a similar effect compared to that of network utilisation.

The magnitude of demand (reaching 839,000 TB per operator in 2021) is large enough that the percentage changes indicated above result in an increase of demand of 8,000 TB on the network. Increasing demand by such an amount significantly increases the economic benefits where the incremental value of any additional capacity is significant. Conversely reducing the demand by such an amount eliminates the need for additional capacity and thus the scenarios become indistinguishable from the baseline case.

5.8 Infrastructure costs

The infrastructure costs used for the CBA above are detailed in Table 5-1 below. These costs are based on professional judgement of current cost information from experience gained working on a recent European regulatory project. In the CBA these costs were assumed to be constant over the analysis period.

Type of cell site	Cost per new cell site (€)	Cost per cell site modification (€)
Femto cells	100	0
Pico cells	24,500	14,000
Micro/macro cells	52,500	30,000

Table 5-1: Cell site costs

A sensitivity analysis was carried out to calculate the impact of the cost changing over time. An annual reduction in price of 2% is applied to the values in Table 5-1 in order to model a time varying set of costs. Table 5-2 illustrated the resulting costs in 2021.

Type of cell site	Cost per new cell site (€)	Cost per cell site modification (€)
Femto cells	80	0
Pico cells	19,600	11,200
Micro/macro cells	42,000	24,000

Table 5-2: Cell site costs in 2021²¹

The following figure illustrates the impact of such time varying costs.

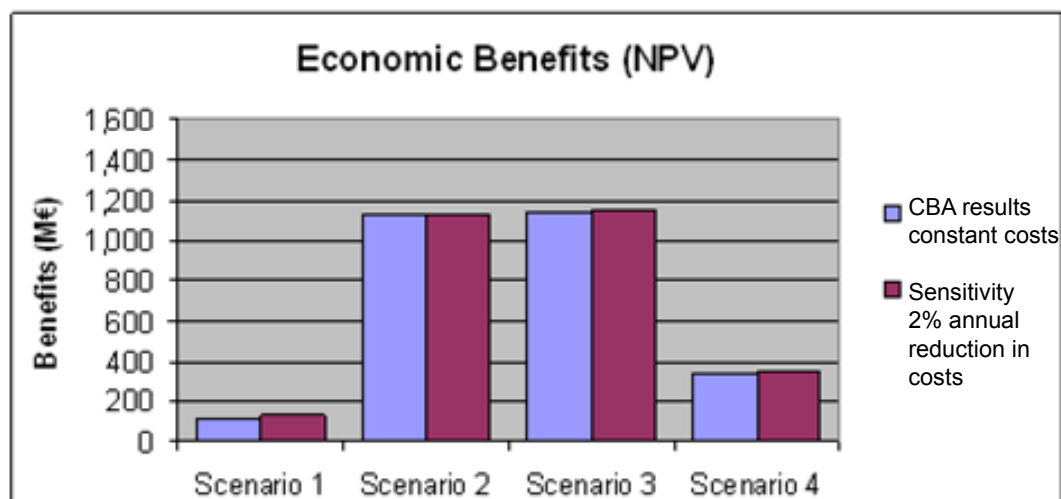


Figure 5-12: 2% annual reduction in infrastructure costs

A marginal increase in economic benefit is observed in scenarios 1 and 4 where the consumer welfare and producer surplus are of the same order of magnitude.

In scenarios 2 and 3 however the producer surplus is the dominant benefit where the revenues in satisfying demand greatly outweigh the costs in providing the required capacity. Such reduction in the infrastructure costs therefore has negligible benefits in these circumstances.

5.9 Number of operators

The number of operators used in the CBA above was assumed to be 3 within the reference country. The figures below illustrate the impact of having 4 or 5 operators within the same country.

²¹ Values rounded to nearest hundred within table

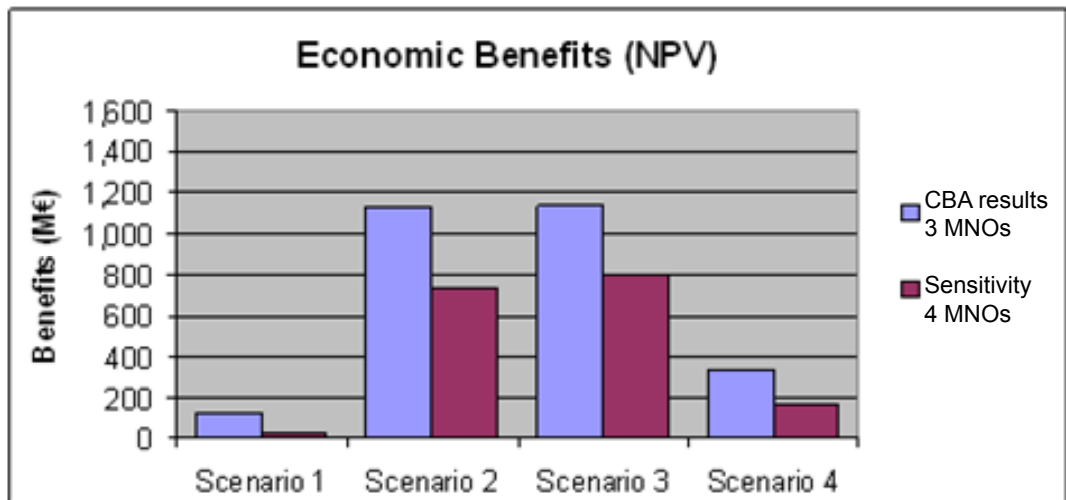


Figure 5-13: 4 operators

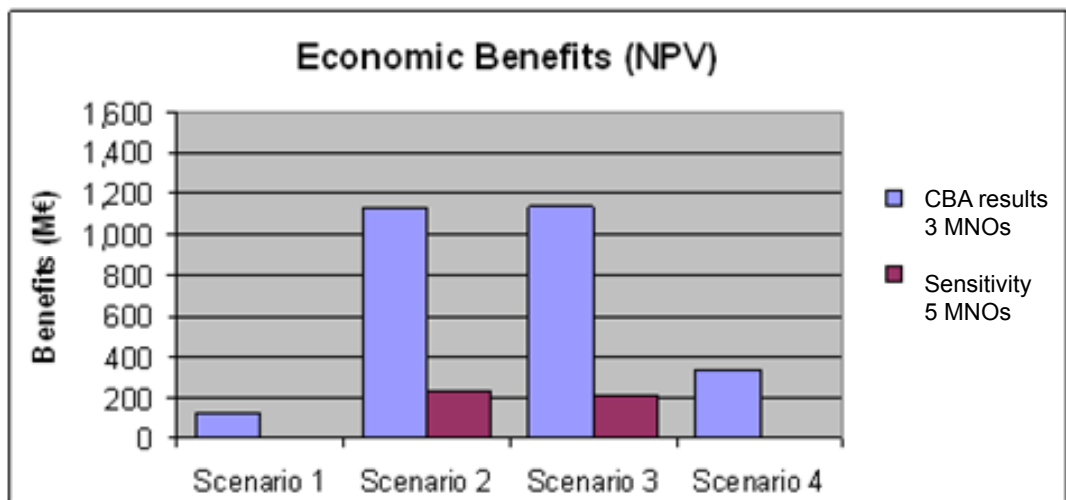


Figure 5-14: 5 operators

Increasing the number of operators in effect reduces the number of subscribers for each network operator reducing in turn the demand, required capacity and subsequent revenues.

In a country where 4 operators are present, whilst the benefits are near halved, both Scenario 2 and 3 still present a clear case of benefits with respect to the baseline. In the case where 5 operators are present, the benefits are significantly reduced however a case for liberalisation still exists.

5.10 Number of subscribers per cell using common content

The number of subscribers per cell site using common content was assumed to be 4 in the CBA above. The figures below illustrate the impact of having either 6 or 8 subscribers per cell site using common content.

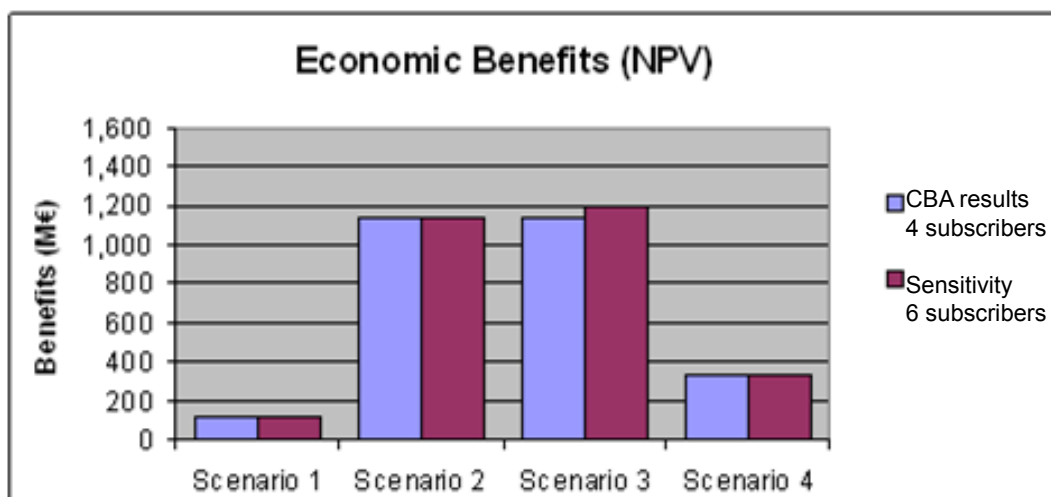


Figure 5-15: 6 subscribers using common content

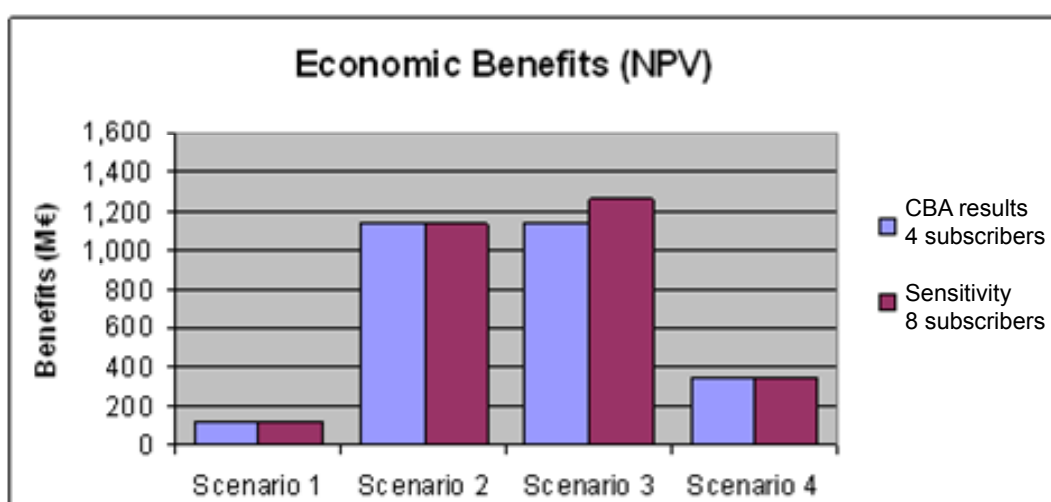


Figure 5-16: 8 subscribers using common content

The sensitivity analysis shows that as the number of subscribers using common content per cell site increases so do the economic benefits for scenario 3. This is because an increased amount of common data is taken off the rest of the network and delivered once via the downlink only service using the TDD bands, resulting in greater capacity increases. Increasing the assumed number of subscribers from 4 to 6 increases the benefits of scenario 3 by 65M€. Increasing the number of subscribers from 4 to 8 increases the benefits by 117M€. The greater the demand for common content the more clearly scenario 3 will emerge as having the greatest economic benefits.

5.11 Different country type case studies

The CBA above was performed for the UK which is assumed to be typical of a country with a large number of subscribers and cell sites (for a single operator) deployed across the coverage area.

The sensitivity analysis below presents case studies for other European countries representative of the range of different types of countries found in Europe:

- Romania - low number of subscribers relative to a high number of cell sites.
- The Netherlands - high number of subscribers relative to a low number of cell sites.
- Slovakia - low number of subscribers relative to a low number of cell sites

The number of subscribers and cell sites for each case study were scaled relative to the UK case study according to country population and area respectively. The resultant case study range was examined:

Case study type				
	UK	Romania	Netherlands	Slovakia
Number of subscribers	High	Low	High	Low
Number of cell sites	High	High	Low	Low
Range of values (per operator)				
Subscribers	20,700,000	7,300,000	5,600,000	1,800,000
Femto cell sites	Scaled to population			
Pico cell sites	3,000	2,800	400	600
Micro/macro cell sites	7,000	6,600	1,000	1,400

Table 5-3: Country case study sensitivity²²

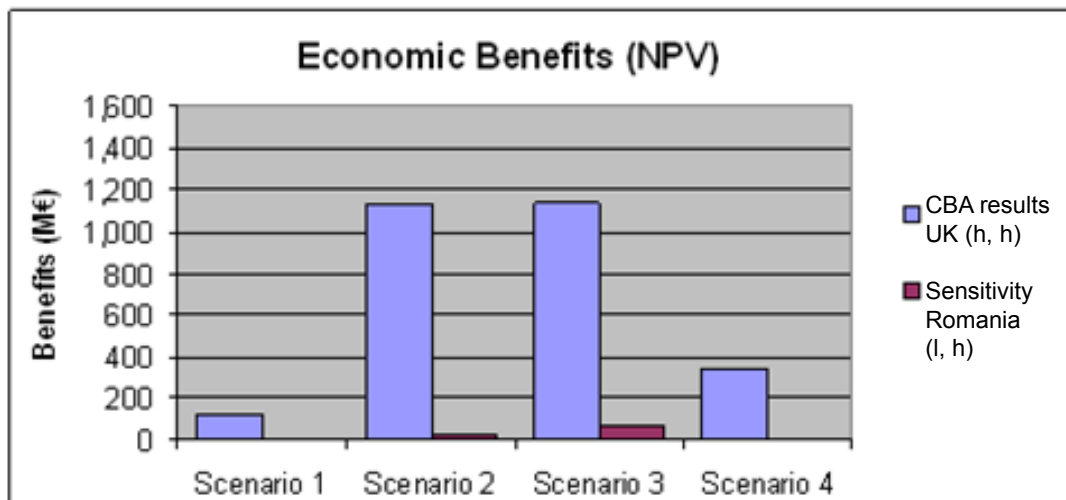


Figure 5-17: Romania case study (low subscribers, high cell sites)

²² Values rounded to nearest hundred within table

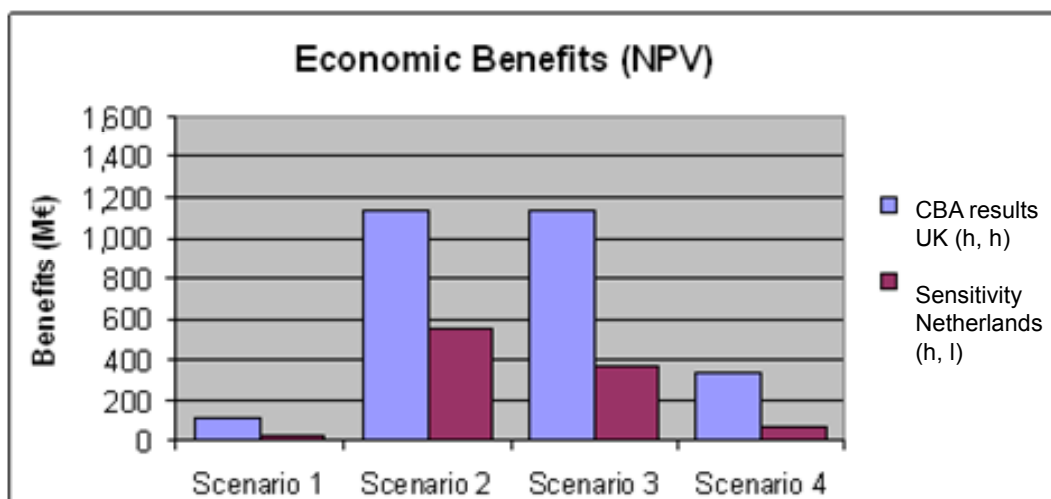


Figure 5-18: Netherlands case study (high subscribers, low cell sites)

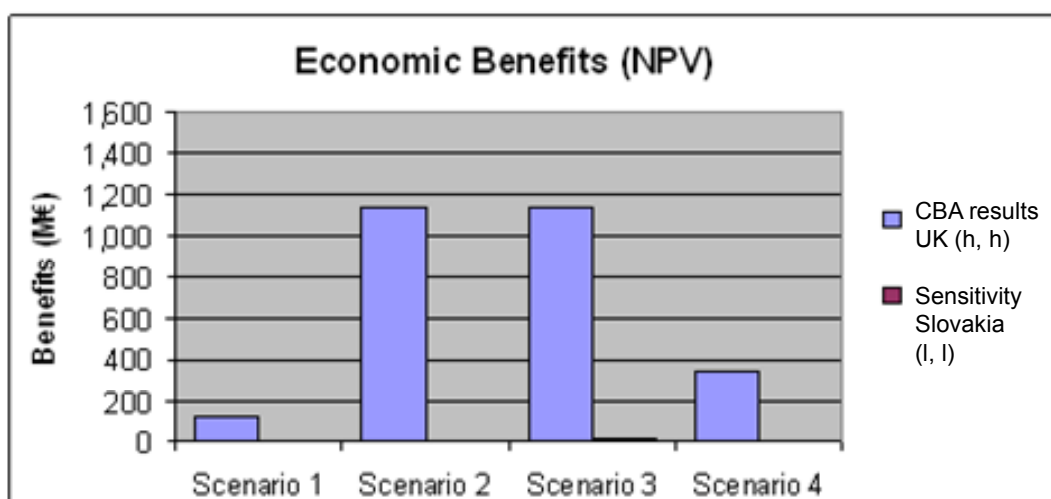


Figure 5-19: Slovakia case study (low subscribers, low cell sites)

The number of subscribers relative to the number of cell sites is a key assumption playing an important role in the determination of overall network demand and the relative infrastructure investment required in order to satisfy it. As a result, only the high-high and high-low case studies yield additional economic benefits across all the scenarios relative to the baseline case where the 2 GHz band continues to be used as it is today. However, it is noted that scenarios 2 and 3 yield additional economic benefits in each of the country type case studies, even if these are only very small in the case of the low-high, and low-low cases.

To give an idea of the overall benefits for the EU the table below shows the approximate split of the EU Member States according to the country types defined above.

Number of cell sites	Number of subscribers	
	High (pop density > 110 per km ²)	Low (pop density ≤ 110 per km ²)
High (country area > 100,000 km ²)	UK France Germany Italy Poland	Romania Bulgaria Finland Greece Sweden Spain
Low (country area ≤ 100,000 km ²)	Netherlands Belgium Czech Republic Denmark Luxembourg Malta Portugal	Slovakia Austria Cyprus Estonia Hungary Ireland Latvia Lithuania Slovenia

Table 5-4: Categorisation of EU member states

From the sensitivity results and table above it can be concluded that, although the economic benefits may differ significantly across Member States, the harmonised implementation of scenarios 2 or 3 would result in economic benefits across the EU relative to the baseline “Do Nothing” scenario.

6 Summary of CBA results

6.1 Introduction

This section provides a summary of the study results. This incorporates both quantitative analysis of the CBA in addition to qualitative considerations highlighted during the consultation with industry stakeholders.

6.2 Quantitative results of CBA analysis

Figure 6-1 below illustrates the available network capacity across each of the scenarios while Figure 6-2 shows the comparison of the economic benefits calculated for each scenario.

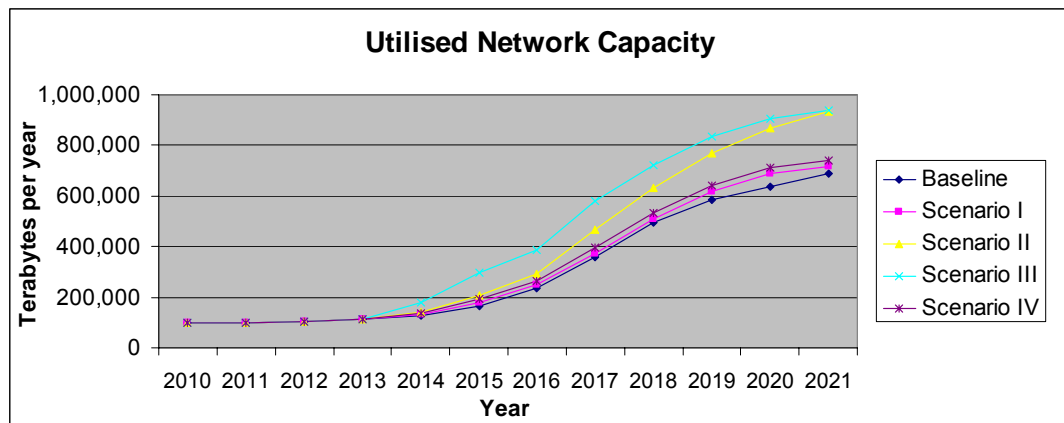


Figure 6-1: Available network capacity considering utilisation

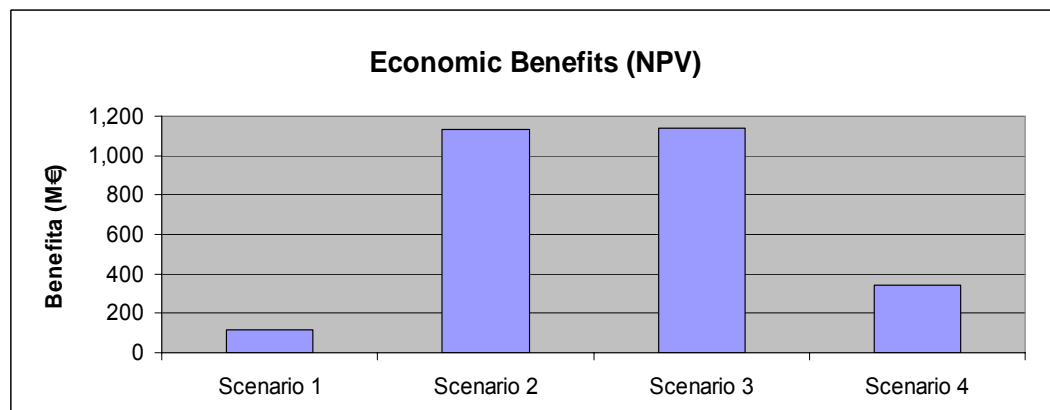


Figure 6-2: Comparison of scenario NPV benefits (relative to baseline)

From the figures it can be seen that scenario 2 (low power TDD) and scenario 3 (downlink only service) result in the greatest economic benefits (~1,100M€ NPV) and also result in the greatest increase in the available capacity with respect to the baseline (35%).

The marginal difference in capacity between scenario 2 and 3 results in negligible additional benefits as in the early years the assessment of consumer welfare and producer surplus remains demand constrained. By the time this switches to a

capacity constrained assessment the benefits are discounted and therefore the difference in capacity has little effect.

Of the two, scenario 3 has the best benefit to cost ratio of 6.02 compared to 3.84 for scenario 2. Scenarios 2 and 3 also consistently remain the most economically beneficial options under the sensitivity analysis. However, the following additional points are noted:

- The economic benefits of scenario 2 and 3 relative to each other depend on some of the assumptions used as input to the CBA (e.g. using a 5% discount rate scenario 2 has the greatest benefits and with a 15% discount rate scenario 3 has the greatest benefits).
- There may not be an economically viable case for using the 2 GHz TDD bands to provide additional capacity in all Member States. Therefore liberalisation of the 2 GHz band may result in little or no primary economic benefits in these countries.
- Considering countries where there is a high number of subscribers it appears that early liberalisation is required to maximise the potential economic benefits in line with the increasing demand for mobile broadband services.

6.3 Additional qualitative considerations

In addition Table 6-1 below compares other non-economic differences between the scenarios. As well as having the highest economic benefit scenario 3 (downlink only services) also offers the greatest potential for additional social benefits. This is based on the fact that this scenario potentially enables the delivery of high bandwidth broadcast applications which are currently not cost-effective using the current FDD bands. This in turn may stimulate the market for the development of a new range of desirable services and applications providing perceived benefits to consumers that would otherwise not be possible. However, these additional benefits are dependent on a market being found for a particular broadcast service or application.

Scenario	Pros	Cons
1 – Macro cells	Supports core MNO services by providing additional capacity for similar voice and data services delivered over FDD today.	<p>Transmissions/reception profile of TDD channel needs to be synchronised.</p> <p>Smaller channel capacities compared to FDD may result in noticeable differences in service quality when roaming between the two.</p>
2 – Femto cells	<p>Lower power means synchronisation of transmission would not necessarily be required.</p> <p>Supports core MNO services.</p> <p>Reduces interference to wide area network if dedicated spectrum used for femto cell layer.</p> <p>Could support M2M communications through spreading data load across femto cells although it is noted that the preferred solution may be using mesh networks instead.</p>	TDD spectrum would be unavailable to provide wide area coverage.
3 – Downlink only services	<p>Potentially enables a new suite of high bandwidth broadcast applications that cannot be cost-effectively delivered over current FDD bands. The value for these services may be perceived by consumers as higher than current voice and data services potentially resulting in higher producer and consumer surpluses than calculated in the CBA.</p> <p>Additional spectrum efficiency gained from providing common downlink only service to multiple operators through spectrum pooling and sharing i.e. a greater number of users make use of common content.</p>	<p>May require Europe wide spectrum pooling or spectrum trading to realise sufficient spectrum for feasible implementation of downlink only services supporting high bandwidth broadcast applications which could result in additional costs or delays in implementation.</p> <p>May require additional handset modifications to support push services that require handsets to cache data transmitted over 2 GHz TDD bands.</p>

Scenario	Pros	Cons
4 – FDD services	Supports core MNO services but without the potential reduction in service quality that may occur in scenario 1.	Identifying a suitable band to pair with is not straightforward and has already been subject to much discussion with no agreement reached. The costs for acquiring the paired spectrum are not taken into account in the CBA but could be significant and would need to be considered on a case by case basis.

Table 6-1: Scenario comparison of non-economic pros and cons

6.4 Other key observations on scenario 3 – downlink only service

The comparison above suggests the using the TDD bands for downlink only service (scenario 3) offers the greatest socio-economic benefits. Here we highlight other key observations relating to this scenario:

- In the years following the BEP the majority of the economic benefits are attributed to producer surplus.
- As identified above scenario 3 appears to give the greatest economic benefits even if the timing of liberalisation changes. In addition it appears that a liberalisation date of around 2013 results in the greatest economic benefit. However, this does not take into account a specific, separately identifiable market demand for high bandwidth broadcast applications.
- The biggest barriers preventing the successful realisation of this scenario are:
 - The identification of a suitable market for the delivery of broadcast or downlink only service over the TDD bands.
 - The possible need for MNOs with existing TDD licences to engage in national or Europe wide spectrum trading or spectrum pooling arrangements in order to make enough spectrum available to implement e.g. IMB/EMBS downlink technologies and services.

7 Final recommendations

Based on the results of the study we can draw the following conclusion:

1. Notwithstanding the current limited use, technological innovation has taken place within the 2 GHz TDD bands even without liberalisation. **Liberalisation is therefore not a pre-condition for innovation** within the band but could facilitate increased innovation through the ability to use a wider range of technologies with different characteristics. However, use of the TDD bands is subject to overcoming the current barriers to its use.
2. The barriers to expansion of the current use of the 2 GHz TDD bands are due to:
 - The difficulties in using the 1900-1920 MHz and 2010-2025 MHz bands because of their narrow bandwidth and the need to protect core mobile voice and data services in the band adjacent to 1900-1920 MHz.
 - The lack of market demand and therefore business case for services to be delivered over TDD instead of FDD bands.
 - The lack of 2 GHz TDD capability in current handsets.
3. Because of the narrow bandwidth, non-harmonised use of the TDD bands requires coordination between MNOs to avoid interference which is restrictive and costly. Therefore, **harmonisation is likely to be critical for any widespread use of the 2 GHz TDD bands** to avoid fragmentation. However, this in turn will reduce flexibility in its use once harmonisation is agreed.
4. There is general support for use of LTE in the 2 GHz bands. Both LTE TDD and FDD will be implemented in the same chipset and will be implemented in high end phones in 1 to 2 years. This will therefore reduce the potential cost of introducing TDD services in the future although it is noted that to use the TDD capability will also need to implement the required RF components for the TDD band.
5. The survey indicated a slight preference for technical harmonisation with LTE as an additional mandatory EU-wide standard as the future policy option for the 2 GHz band (both TDD and FDD). On the other hand this study does not identify any negative effects of opening the bands to other standards.
6. It has been stated by MNOs that the 2 GHz FDD spectrum would continue to be used for core mobile voice and data service in the future using either improvements to UMTS or LTE.
7. The survey of stakeholders including existing 2 GHz licence holders identified that the most likely use of the 2 GHz TDD bands in the future was to provide additional mobile broadband data capacity and that TDD was seen as being particularly suited to asymmetrical data services.
8. The CBA shows that the use of the TDD bands for downlink only services generally results in the greatest potential social and economic value of the scenarios investigated. However, it is noted that low power TDD for indoor/home use also results in significant socio-economic benefits which under some circumstances may be greater than that of the downlink only services.

9. The CBA sensitivity analysis shows that although the economic benefits may differ significantly across Member States, the harmonised implementation of downlink only services or low power TDD would result in economic benefits across the whole of EU.
10. The CBA shows that the harmonised use of the TDD bands for downlink only service gives the greatest economic benefits with an optimal liberalisation date of around 2013. This scenario also potentially enables greater social and economic benefits through the development of innovative high bandwidth broadcast services and applications that have a perceived high value by consumers compared to current data applications and services.
11. In support of a downlink only scenario Europe-wide spectrum trading and/or spectrum pooling/sharing would enable greater spectrum efficiency by delivering common content to users of multiple operators and would also encourage the successful implementation of high value high bandwidth broadcast and/or push type services.
12. Alternative uses of the 2 GHz TDD bands for services other than mobile broadband data have also been identified. However, the existing rights of use of the band still need to be considered and any alternative use would need agreement from existing licence holders; furthermore existing licences may need to be re-issued or traded.
13. Use of the 2 GHz TDD bands for M2M communications (e.g. to support smart meters or home appliances) is one such potential alternative use of the bands. A qualitative analysis indicates that:
 - M2M communication technologies have already been developed within the 3GPP standards and could be used under existing licence conditions.
 - this use may suit the characteristics of the TDD bands; and,
 - there could be a wider range of social benefits compared to the preferred downlink only scenario due to the wider range of stakeholders affected and in particular the potential positive impact on the environment.
 - This potential alternative use appears to be an attractive alternative with a wide range of potential benefits that is worthy of detailed investigation in its own right to further quantify the socio-economic benefits in comparison with the preferred downlink only mobile broadband scenario identified above.
14. M2M communication for smart grids is only one possible alternative use of the 2 GHz TDD bands. Other options for the 2 GHz TDD bands to enable services not currently under consideration (e.g. its use for CNI/PPDR networks) may offer higher overall economic benefits than liberalisation for additional mobile broadband usage and the Commission may wish to consider these options further.
15. A decision by the Commission to liberalise the 2 GHz bands (only for LTE) may not, therefore, necessarily lead to the highest overall economic outcome and the Commission may wish to consider alternative uses which may be enabled by a wider opening up of the use of the bands.

Based on these conclusions the following recommendations are made in support of a Commission Decision on the harmonised use of the 2 GHz band. The future policy should consider:

1. Liberalisation of the whole 2 GHz band based on mandatory, EU-wide application of the technical conditions in CEPT 39, which will most likely lead to the harmonised use of LTE in addition to UMTS in the near term.
2. A liberalisation date which supports the initial roll-out of next generation mobile networks (such as LTE) from 2013 onwards in line with the increasing demand for mobile data services.
3. Permitting the harmonised use of the 2 GHz TDD bands for downlink only services.
4. Encouraging spectrum trading as well as collective or shared spectrum use with the objective of facilitating the transfer of licences to, or collaborative use of, licences by stakeholders that have a real need to use the spectrum. This should apply in particular to the TDD bands and facilitate the aggregation of spectrum holdings, which may result in a single holder of rights or a virtual single network operating in each of the TDD bands.

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B Glossary

3GPP	3rd Generation Partnership Project
B/C	Benefit to Cost Ratio
BEP	Break Even Point
CBA	Cost Benefit Analysis
CEPT	European Conference of Postal and Telecommunications Administrations
EC	European Commission
ECC	Electronic Communications Committee
EMBS	Evolved Multicast Broadcast System
EU	European Union
FDD	Frequency Division Duplex
GB	Giga Byte
IMB	Integrated Mobile Broadband
LTE	Long Term Evolution
M2M	Machine To Machine
MB	Mega Byte
MNO	Mobile Network Operator
NASA	National Aeronautics and Space Administration
PPDR	Public Protection Disaster Relief
NPV	Net Present Value
TB	Terra Byte
TDD	Time Division Duplex
UMTS	Universal Mobile Telecommunication System
WIMAX	Worldwide Interoperability for Microwave Access

C Stakeholder survey questionnaires

Two survey questionnaires were produced: one aimed at service providers and network operators; and one aimed at equipment manufacturers. These were used to capture information against specific questions as well as to facilitate discussions during interviews with specific stakeholders. The survey questionnaires are included below.

C.1 Operators and service providers

Stakeholder survey

Impact of liberalisation of 2 GHz frequency band

Operators and service providers

The survey consists of 11 questions. Your input will feed into a study conducted on behalf of the European Commission. All responses will be treated confidentially.

Liberalisation of the use of the 2 GHz band through the introduction of service and technology neutrality would potentially enable the use of technologies other than UMTS and the use of services other than mobile telephony. In Europe the 2 GHz band is currently allocated for use by UMTS Frequency Division Duplex (FDD) and Time Division Duplex (TDD) services. Specifically, the 2 GHz band consists of the 1920-1980 MHz band paired with the 2110-2170 MHz band for FDD services and the 1900-1920 MHz and 2010-2025 MHz unpaired bands for TDD services. However the demand to use the unpaired spectrum in the 2 GHz band is currently low. This unpaired spectrum may therefore provide much greater benefits as a result of a more liberal allocation of the 2 GHz band allowing the use of other technologies.

For a full explanation of the purpose of this survey, please see the attached letter.

This survey can also be completed online at www.surveymonkey.com/s/2ghztddsurvey

About you

First name: Last name:

Job title:

Organisation: Country:

Email address:

Your current service plans

Q1	What is your current spectrum assignment in the 2 GHz bands (paired and unpaired) and what date does it expire?

Q2	Do you currently operate any services in the unpaired spectrum (1900-1920 MHz and 2010-2025 MHz)? If YES, please describe below. If NO, and you hold unpaired spectrum, please explain why below.	<input type="checkbox"/> YES <input type="checkbox"/> NO
Q3	Do you have any plans to utilise this spectrum in the near future? If YES, please provide a short description below. If NO, please briefly explain why below (if not covered by Question 2) and indicate what would be required for this to change.	<input type="checkbox"/> YES <input type="checkbox"/> NO
Q4	Would your service plans be altered if the use of the 2 GHz band were liberalised? If YES, please explain why below.	<input type="checkbox"/> YES <input type="checkbox"/> NO
Your views on the future use of the 2 GHz bands		
Q5	What kind of services would you envisage the 2 GHz bands being used for in the future?	
Q6	What do you perceive is the added value of harmonising the use of 2 GHz band for the use of technologies other than UMTS?	

Q7	<p>CEPT report 39²³ was developed by CEPT in response to a mandate from the European Commission and contains the technical basis upon which the EC would base itself for drafting a Commission technical harmonisation Decision.</p> <p>Are you aware of the power limit constraints specified in CEPT Report 39 for use of the 1900-1920 MHz and 2010-2025 MHz bands?</p> <p>If YES, what will be the impact of the power limits specified in the CEPT report on the services you currently provide (or could provide) following a more liberal use of the 2 GHz band?</p> <p>AND, what would be the impact of less restrictive in-band power limits, i.e. a maximum EIRP for base stations of 61 dBm/5MHz in the band 1900-1915 MHz and a maximum EIRP of 25 dBm/5MHz in the band 1915-1920 MHz (cost / benefit) ?</p>	<input type="checkbox"/> YES <input type="checkbox"/> NO
	<p style="text-align: right;"><i>Please continue on page 3</i> <i>Answer to Question 7 (continued)</i></p>	
Q8	<p>Concerning the 1900-1920 MHz and 2010-2025 MHz frequency band, ECC confirmed that in case of multiple operators in this band, the technical conditions according to CEPT Report 39 would drastically constrain the usage of the band in the absence of synchronisation of TDD networks or other mitigation techniques.</p> <p>Would your organisation benefit from the pooling of spectrum in the unpaired 2 GHz bands to overcome inter-operator guard-band issues (i.e. using a neutral host)?</p>	<input type="checkbox"/> YES <input type="checkbox"/> NO
Q9	<p>What % increase in service revenue would your organisation likely see following liberalisation of the use of the 2 GHz bands?</p>	
Q10	<p>Please indicate your TOP TWO preferred options for the future use of the 2GHz bands from the options below. (1 = most preferred option; 2 = next preferred option.)</p>	

²³ www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP039.PDF

	No change – future use of 2 GHz band is the same as current use.	
	Technical harmonisation with LTE as the only additional standard with a mandatory EU wide allocation.	
	Implementation of service and technology neutrality in the band through early policy implementation.	
	The implementation of service and technology neutrality in the band through later policy implementation (with the option for earlier action at a national level).	
Q11	Do you support the measures below? Please indicate on a scale from 1 to 5 your preference (1 = fully supported; 5 = not supported at all.)	
	Pooled spectrum to overcome inter-operator guard-band issues.	
	Use unpaired spectrum in band as uplink/downlink only with paired spectrum in another band (and if so, which ones?)	
	Other (please describe below).	

Any other comments?

Please use another sheet as necessary

Thank you for your time and cooperation

Please return this questionnaire by 5th August 2011 to:

Adam Parkinson

Helios
29 Hercules Way
Aerospace Boulevard
AeroPark
Farnborough
Hampshire
GU14 6UU
UK

Any queries in relation to this survey can be addressed to:

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C.2 Equipment manufacturers

Stakeholder survey

Impact of liberalisation of 2 GHz frequency band

Equipment manufacturer

The survey consists of 10 questions. Your input will feed into a study conducted on behalf of the European Commission. All responses will be treated confidentially.

Liberalisation of the use of the 2 GHz band through the introduction of service and technology neutrality would potentially enable the use of technologies other than UMTS and the use of services other than mobile telephony. In Europe the 2 GHz band is currently allocated for use by UMTS Frequency Division Duplex (FDD) and Time Division Duplex (TDD) services. Specifically, the 2 GHz band consists of the 1920-1980 MHz band paired with the 2110-2170 MHz band for FDD services and the 1900-1920 MHz and 2010-2025 MHz unpaired bands for TDD services. However the demand to use the unpaired spectrum in the 2 GHz band is currently low. This unpaired spectrum may therefore provide much greater benefits as a result of a more liberal allocation of the 2 GHz band allowing the use of other technologies.

For a full explanation of the purpose of this survey, please see the attached letter.

About you

First name: Last name:

Job title:

Organisation: Country:

Email address:

Your current products

Q1	Do you currently manufacture any equipment for the unpaired 2 GHz bands? If YES, please describe the equipment. If NO, go to Question 4.	<input type="checkbox"/> YES <input type="checkbox"/> NO
Q2	How successful have these products been in comparison to other equipment operated at 2 GHz?	
Q3	How do the costs of these products differ from other equipment operated at 2 GHz and in other bands?	
Q4	Have you been able to integrate unpaired 2 GHz solutions into your current products? If NO, do you see this becoming possible in the future?	<input type="checkbox"/> YES <input type="checkbox"/> NO

Your views on the future use of the 2 GHz bands

Q5	<p>How soon and for which technologies would you see suitable equipment becoming available following liberalisation of the 2 GHz band?</p>
Q6	<p>What do you perceive is the added value of harmonising the use of 2 GHz band for the use of technologies other than UMTS?</p>
Q7	<div style="display: flex; justify-content: space-between;"> <div style="width: 80%;"> <p>CEPT report 39²⁴ was developed by CEPT in response to a mandate from the European Commission and contains the technical basis upon which the EC would base itself for drafting a Commission technical harmonisation Decision.</p> <p>Are you aware of the power limit constraints specified in CEPT Report 39 for use of the 1900-1920 MHz and 2010-2025 MHz bands?</p> <p>If YES, what will be the impact of the power limits specified in the CEPT report on the services you currently provide (or could provide) following a more liberal use of the 2 GHz band?</p> <p>AND, what would be the impact of less restrictive in-band power limits, i.e. a maximum EIRP for base stations of 61 dBm/5MHz in the band 1900-1915 MHz and a maximum EIRP of 25 dBm/5MHz in the band 1915-1920 MHz (cost / benefit) ?</p> </div> <div style="width: 15%; text-align: right;"> <input type="checkbox"/> YES <input type="checkbox"/> NO </div> </div> <div style="text-align: right; margin-top: 20px;"> <p><i>Please continue on page 3</i></p> <p><i>Answer to Question 7 (continued)</i></p> </div>
Q8	<p>What % increase in service revenue would your organisation likely see following liberalisation of the use of the 2 GHz bands?</p>

²⁴ www.ero-docdb.dk/Docs/doc98/official/pdf/CEPTREP039.PDF

Thank you for your time and cooperation

Please return this questionnaire by 5th August 2011 to:

Adam Parkinson
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D Individual survey responses

The individual survey responses have been provided to the European Commission as a separate document. The individual responses are only for internal distribution and use within the Commission.

E Network cost assumptions

The following table shows the costs assumed for installing new or upgrading existing cell site in a mobile network. These estimates have been based on Helios's own professional knowledge and judgement of typical network costs due to our experience gained from working on a recent European regulatory project.

Note that femto cell sites were assumed to be implemented in broadband routers used in the home and therefore the cost of implementation was assumed to be negligibly small.

Cell site type	Cost per new cell site (€)	Cost for cell site modification (€)
Femto cell sites		
GSM (€)	100	0
UMTS (€)	100	0
LTE (€)	100	0
Pico cell sites		
GSM (€)	24,500	14,000
UMTS (€)	24,500	14,000
LTE (€)	24,500	14,000
Macro/micro cell sites		
GSM (€)	52,500	30,000
UMTS (€)	52,500	30,000
LTE (€)	52,500	30,000

The following table shows the costs assumed for providing additional backhaul capacity based. These costs have been derived from [11].

Threshold capacity (MB/s)	Backhaul cost per cell site (€) per Mbps
Femto cells	0 ²⁵
100-300	28
300-600	7
600-900	5
>900	3

²⁵ Femto cell backhaul is assumed to use existing broadband connections and thus no additional backhaul costs have been included.