Re-thinking the Digital Agenda for Europe (DAE): *A richer choice of technologies*

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Re-thinking the Digital Agenda for Europe (DAE): A richer choice of technologies

Independent analysis conducted by WIK-Consult GmbH on behalf of Liberty Global

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EXECUTIVE SUMMARY

The goals of the Digital Agenda for Europe (DAE), which seeks to ensure widespread deployment and availability of ultra-fast broadband throughout the European Union, are generally sensible and well known; however, it will be challenging to meet them.

Many of the initial pronouncements on ultra-fast broadband at European and national level focused exclusively on fibre-based solutions such as FTTN/VDSL and FTTB/FTTH; more recently, however, there has been an increasing and welcome recognition of the potential merits of a balanced solution that draws on a mix of technologies, including not only fibre but also cable and fixed and mobile wireless.

Cable can and does serve (1) as an alternative to making FTTx upgrades, especially in areas where the cost of fibre upgrades would be particularly uneconomic, thus providing cost savings; and (2) as a second fixed network in a given area, providing a facilities-based fixed network alternative to an FTTx network, thus enhancing competition.

Wireless also functions in a useful complementary role (1) to provide coverage in low density and/or high cost areas, (2) as a competitive alternative to fixed network solutions, and (3) wherever mobility is needed.

Benefits of conventional broadband and ultra-fast broadband

The various studies on the value of broadband consistently find significant benefits from broadband deployment and adoption. There is considerable uncertainty, however, over the degree to which greater broadband speed produces greater benefits.

An interesting recent study by Greenstein and McDevitt on behalf of the OECD might suggest that broadband benefits, measured by consumer Willingness to Pay (WTP) for broadband, may be greater in countries where competition is more effective.

The goals of the Digital Agenda for Europe

The goals of the Digital Agenda for Europe (DAE) are well known: (1) availability of broadband for all Europeans in 2013, (2) deployment of 30 Mbps broadband capability to all Europeans by 2020, and (3) adoption of 100 Mbps broadband by 50% of European households by 2020.

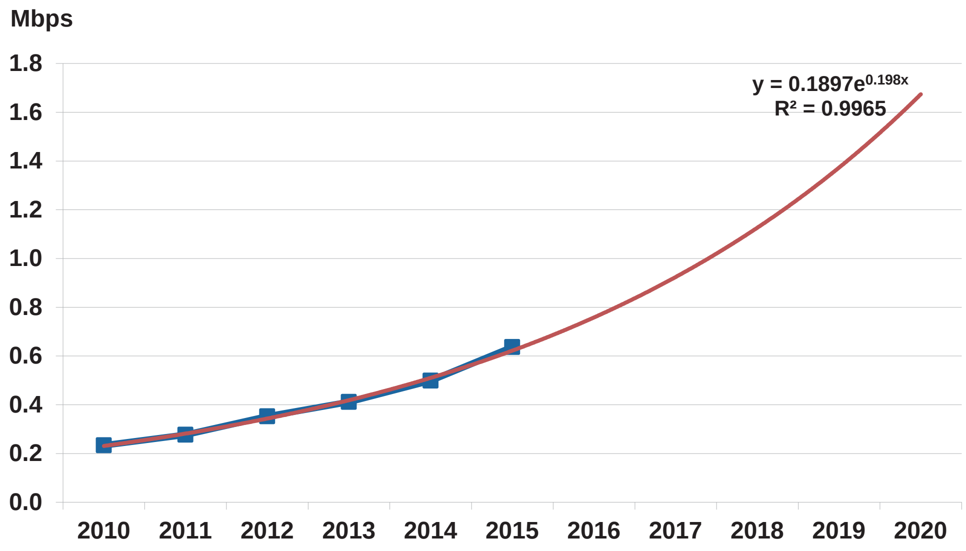
The detailed meaning of these goals is, however, less clear. What do these speeds really mean, and to what extent must they be reflected in the core network?

We would propose that the DAE objectives should be interpreted such that networks are designed to provide performance that consumers perceive as acceptable for the applications that they want to run.

This view argues against a static interpretation of the DAE objectives; rather, the interpretation should track trends in consumer demand for broadband.

Consumer demand for bandwidth has steadily grown over the last decade, albeit at a percentage rate of growth that is declining over time. Even so, consumer bandwidth demand per household is less than many assume, even though total global bandwidth demand is substantial. Per projections based on Cisco VNI data, average global bandwidth demand per household in 2020 (the target data for achieving the DAE's objectives for ultra-fast broadband) is less than 2 Mbps.

The evolution over time of consumer bandwidth demand during the busy hour



Source: Cisco VNI 2011 data,[1] WIK calculations.

Ultra-fast broadband access is useful, but in light of realistic consumer demand it is not necessary to assume that every broadband user will consume maximum capacity all the time. The network should assume some shared use of bandwidth. Portions of the network where capacity is shared can be incrementally enhanced as demand grows.

Ability of different technologies to meet realistic consumer demand

EuroDOCSIS 3.0 cable systems already comfortably exceed the 100 Mbps called for in the DAE. Even with current technology, cable networks are capable of meeting realistic bandwidth demand well in excess of that which is likely to be required in 2020 and considerably beyond.

Under reasonable assumptions of technical improvements in cable, cable networks are likely to remain viable for future ultra-fast broadband for extended periods into the future.

1 Cisco VNI (2011a): "Entering the Zettabyte Era", 1 June 2011.

Similar considerations apply to 4G wireless systems. There are surely limitations on the ability of wireless solutions alone to meet DAE objectives in dense population centres, but wireless might play a greater role in low-to-medium density areas than many have assumed.

Broadband coverage in Europe today

There are many different technologies that could be used to meet DAE objectives, notably including the fixed telecommunications network, but also including cable television networks, as well as fixed and mobile wireless services.

In assessing the current status, it is important to distinguish between the coverage or deployment of each technology, versus adoption (i.e. the degree to which consumers choose to subscribe to the service).

Each technological platform is benefitting in many ways from technological enhancements over time.

- The maximum speed of fibre-based FTTC/VDSL systems could benefit from vectoring, and to a lesser extent from pair bonding and phantom DSL.
- Cable systems benefit in the near term from progressive deployment of EuroDOCSIS 3.0 technology, from the bonding of more channels together under EuroDOCSIS 3.0, from driving fibre deeper into the cable network, and potentially in the longer term from a reallocation of frequencies on the cable.
- Wireless systems benefit from deployment of LTE, and eventually from the deployment of LTE-Advanced.

The relative cost of achieving each of the DAE objectives with each of these technologies can vary greatly. Those costs depend to a significant degree on the coverage footprint of the technology.

- For the fixed telecommunications network, there are significant uncertainties as to the quality of currently available data. A study that has been conducted on behalf of the European Commission will hopefully provide clarity.
- For cable, large portions of Europe have already been upgraded to EuroDOCSIS 3.0. Within the 2020 DAE planning horizon, substantially all European cable will have been upgraded to EuroDOCSIS 3.0 (if not to a successor).
- For wireless broadband, the footprint of LTE and LTE-Advanced can be expected to be at least as broad in 2020 as that of 2G and 3G networks today.

Achievement of full broadband coverage (and especially of ultra-fast broadband) in Europe is complicated by (1) variations in population density from region to region; (2) challenging topography in portions of Europe; and (3) possibly by gaps in coverage of the fixed network in parts of Eastern Europe.

Achievement of the DAE objectives for deployment and adoption of ultra-fast broadband is further complicated by an apparent gap between the cost of deployment, and the maximum price that consumers are willing to pay. Multiple studies, including a recent WIK study of Germany that is summarised here, suggest that full achievement based solely on fibre-based telecommunications solutions is unlikely without some degree of public policy intervention and/or subsidy.

Factoring cable broadband and wireless broadband into the analysis can help significantly to close this gap (as we shall demonstrate in Chapter 6); however, the effects will vary among the Member States, in part as a function of the degree of coverage of the cable television network.

Technical characteristics of a cable broadband network

Our focus in this study is on systems that are based on *Hybrid Fibre Coaxial (HFC)* cable, thus using coaxial cable at the point of access by the customer. The evolution of cable systems is intertwined with that of the telephony network, and that the evolution of both (and, for that matter, also the evolution of the mobile network) is to a significant degree fibre-based.

Cable systems today are far more technically advanced than many realise. They have evolved into Hybrid Fibre Coaxial (HFC) networks that combine many of the best characteristics of coaxial cable systems with those of a high capacity fibre optic-based distribution system.

The upgrade to HFC cable systems to enable state-of-the-art bandwidth is comprised of two distinct processes: (1) upgrade to EuroDOCSIS 3.0 standards, and (2) driving fibre progressively closer to the end-user as and when needed to meet customer demand.

- The cost of upgrading existing digital cable systems to EuroDOCSIS 3.0 is minimal.
- The cost of driving fibre into the network can be significant; however, the upgrade can be undertaken as and when needed. This cost can vary greatly depending on how the existing cable plant was deployed, and also as a function of labour costs that vary among the Member States. In any event, upgrading existing digital cable is substantially less expensive than deploying new fibre-based telecommunications networks, thanks to the benefits of sharing existing coaxial cable to multiple customer premises. Moreover, these upgrades have been in progress for some time (and are continuing), so part of the cost has already been incurred.

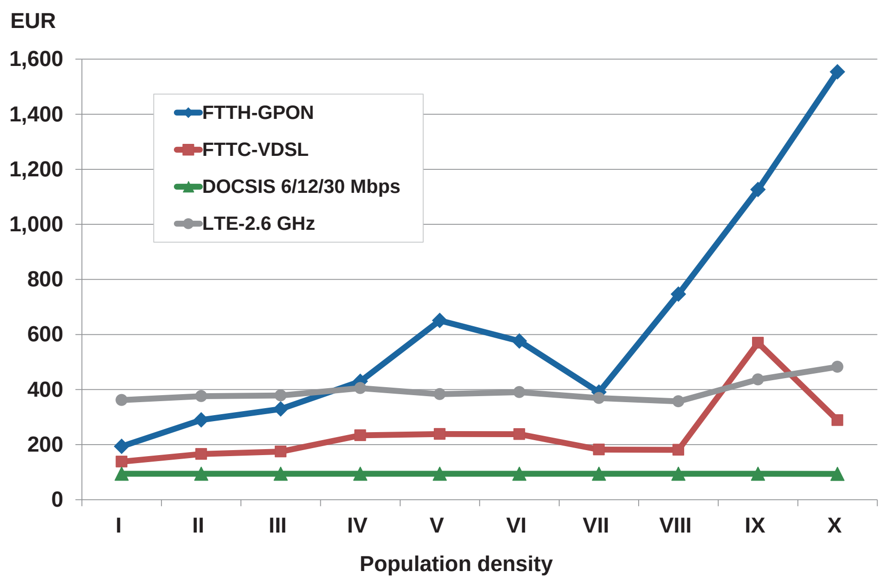
There is no imbalance between the cost of incrementally upgrading cable systems in comparison with customer willingness to pay for the upgrades; consequently, there is no need for subsidy.

Many capacity enhancements improve both upstream and downstream capacity. A more comprehensive approach to bringing upstream capacity in line with downstream would depend on a reallocation of the cable frequency plan, moving the diplex split to a value higher than the current 65/85 MHz. This is entirely possible, and has been under study for some time. The industry has seen no urgency in putting such a solution in place because there has been little customer demand for upstream data bandwidth. The biggest single impediment is that such a shift would conflict with analogue FM radio (which enjoys significant use in some markets) at 88 to 108 MHz.

Costs of meeting DAE goals

Studies of incremental deployment costs of ultra-fast broadband in Spain by Feijoo and Barroso found that population density plays a huge role. LTE was more expensive than fixed solutions where population density exceeded 3,000 inhabitants per square kilometre (Km2). Conversely, upgrades to VDSL or to FTTH became more expensive on a per-subscriber basis as the population density declines. Cable costs (for areas where digital cable, but not necessarily EuroDOCSIS 3.0, is already deployed) are, by contrast, largely independent of density.

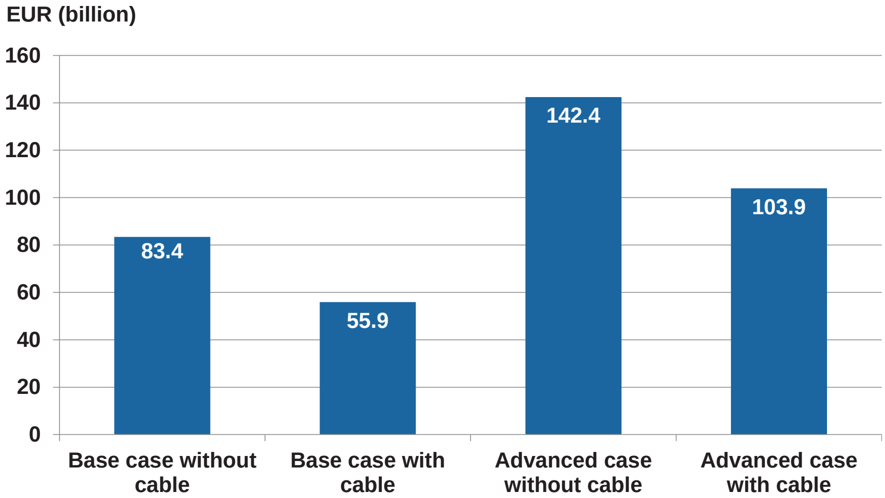
Annualized cost (Present Value) of CAPEX per user (€)



Source: Feijoo / Gomez-Barroso (2010a).

The recently published study by J. Hätönen of the European Investment Bank (EIB), represents one of the few studies of the costs of achieving DAE goals that explicitly considers technologies other than FTTx. They address ambiguities in the definition of the DAE goals by means of four scenarios, two of which (Basic and Advanced) are realistic in our view. Under these scenarios, the use of cable potentially reduces cost of meeting DAE objectives by up to 30%.

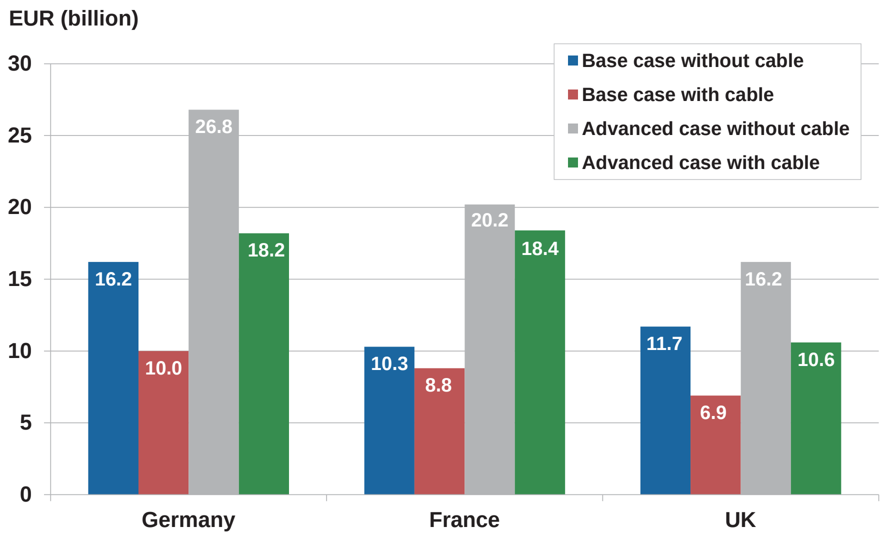
Aggregate incremental cost of achieving DAE objectives for the EU as a whole, with and without cable



Source: Hätönen (2011), WIK calculations.

The results (in terms of savings per household) differ greatly among the Member States (largely as a function of the degree to which cable is deployed).

Incremental cost of meeting DAE objectives with and without cable, Basic and Advanced scenarios, in Germany, France and the UK



Source: Hätönen (2011), WIK calculations.

Whether policymakers would prefer to take that “Cable Dividend” as a cost savings, rather than a gain in facilities-based competition, is a separate question.

The Feijoo/Barroso and EIB studies seem to be in reasonably good agreement for Spain, where they overlap.

Facilities-based infrastructure competition

The European regulatory framework for electronic communications has always advocated an approach to regulation that is, insofar as practicable, technologically neutral.

Given this preference of the Regulatory Framework for technological neutrality, and for infrastructure competition, it is striking that the Digital Agenda for Europe contains only a single reference to cable television – and that an altogether backward-looking statement.

More recent statements from Commissioner Kroes appear to reflect a gradual, welcome shift to a more technologically agnostic posture.

Cable provides facilities-based infrastructure competition. The value of infrastructure competition is explicitly recognised in the European Regulatory Framework.

Infrastructure-based competition is important in the long term. A European network environment where only a single medium provides last mile access is a European network environment where detailed regulation to address market power is needed forever.

Cable tends to enjoy low unit costs in providing broadband services at whatever speed. This puts pressure on incumbents to innovate, and to operate efficiently.

Infrastructure competition is a valuable complement to SMP-based regulation. For instance, it can help to correct for any errors in regulatory price-setting.

A recent WIK study found a strong link between DOCSIS 3.0 coverage and FTTN/VDSL roll-out (typically by the incumbent), but no statistically significant relationship between DOCSIS 3.0 coverage and FTTH/FTTB roll-out. This suggests that incumbents find FTTN/VDSL to be an adequate response to cable.

A recent analysis by Feijoo and Barroso of potential NGA deployment in Spain distinguishes between areas of “2+” competition, where the fixed network, cable and mobile all compete, versus “1+” competition, where only fixed and mobile compete. Facilities-based inter-modal competition, even if limited to discrete geographic areas, may have the tendency to constrain prices to reasonable levels across much larger geographic areas.

Overall assessment

A more technologically neutral approach to the DAE, drawing on cable and LTE, could provide real benefits.

Cable can and does serve as (1) an alternative to making FTTx upgrades, especially in areas where the cost of fibre upgrades would be particularly uneconomic, providing cost savings; or (2) as a second fixed network in a given area, providing a facilities-based fixed network alternative to an FTTx network, thus enhancing competition.

Wireless also functions in a useful complementary role (1) to provide coverage in low density and/or high cost areas, (2) as a competitive alternative to fixed network solutions, and (3) wherever mobility is needed.

GLOSSARY

ADSL/ ADSL2	Asymmetric Digital Subscriber Line (version 2); the most common technology for providing consumer broadband services over copper telephone lines
ARPU	Average Revenue per User
BW	Bandwidth; the capacity of a channel to carry information, typically expressed in bits per second
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CMTS	Cable Modem Termination System; see Section 5.1
DAE	Digital Agenda for Europe
DHCP	Dynamic Host Configuration Protocol
DOCSIS 2.0/ EuroDOCSIS 3.0	Data Over Cable Service Interface Specification (version 2/3); see Section 5.2
DSL	Digital Subscriber Line; family of standards for providing broadband access over copper telephone lines
DSLAM	Digital Subscriber Line Access Multiplexer; a DSLAM is a network device that is commonly provided by telecommunications operators; it connects multiple costumer digital subscriber lines to the network
EIB	European Investment Bank
EU	European Union
FTTx	Fibre to the “x”; x = N, C, B, H; see Section 4.1.1
FTTN	Fibre to the Node; fibre is deployed up to the Main Distribution Frame; the entire local loop between MDF and the end user is still based on copper
FTTC	Fibre to the Cabinet; see Section 4.1.1
FTTB	Fibre to the Building; see Section 4.1.1
FTTH	Fibre to the Home; see Section 4.1.1
GB	Gigabyte
GDP	Gross domestic product
GHz	GigaHertz
GPON	Gigabit Passive Optical Network; in a GPON system the bandwidth is shared by all users connected to a given splitter; see Section 4.1.1
HE	Headend
HFC	Hybrid Fibre Coaxial; cable network based on fibre and coaxial physical transmission infrastructure; see Section 5.1
KPN	“Koninklijke KPN N.V.”, Dutch telecommunications company

LTE/LTE-Advanced	Long-Term-Evolution, the newest standards for wireless communication of high-speed data
Mbps	Mega bit per second (one million bits per second)
MDF	Main distribution frame
MDU	Multiple Dwelling Unit
MHz	MegaHertz
NBN	National Broadband Network (Australia)
NGA	Next Generation Access
NOC	Network Operation Centre
NPV	Net Present Value
NRA	National Regulatory Authority
OECD	Organization for Economic Co-operation and Development
OPEX	Operating Expenditure
PSTN	Public Switched Telephone Network
P2P	Point-to-Point; an architecture based on a single dedicated fibre strand (or a fibre pair) for each end user between an Optical Street Distribution Frame and the end user
ROI	Return on Investment
RSPG	Radio Spectrum Policy Group
RSPP	Radio Spectrum Policy Program
SMP	Significant Market Power; a firm is "… deemed to have significant market power if, either individually or jointly with others, it enjoys a position equivalent to dominance, that is to say a position of economic strength affording it the power to behave to an appreciable extent independently of competitors, customers and ultimately consumers" (Framework Directive)
SMTP	Simple Mail Transfer Protocol
TB	Terabyte (1 Terabyte = 1000 Gigabytes)
VDSL/ VDSL2	Very High Speed Digital Subscriber Line (version 2); see Section 4.1.1
VNI	Virtual Networking Index (published by Cisco)
VoD	Video-on-Demand; a Video on Demand enables end-users to select and watch video content over a network
WiMAX	Worldwide Interoperability for Microwave Access
WTP	Willingness to Pay
4G	Fourth-generation mobile communication standard

1 INTRODUCTION

Key Findings

Key Findings

- The goals of the Digital Agenda for Europe (DAE), which seeks to ensure widespread deployment and availability of ultra-fast broadband throughout the European Union, are generally sensible and well known; however, it will be challenging to meet them.

- Many of the initial pronouncements on ultra-fast broadband at European and national level focused exclusively on fibre-based solutions such as FTTN/VDSL and FTTB/FTTH; more recently, however, there has been an increasing recognition of the potential merits of a balanced solution that draws on a mix of technologies, including not only fibre but also cable and wireless.

- Cable can and does serve (1) as an alternative to making FTTx upgrades, especially in areas where the cost of fibre upgrades would be particularly uneconomic, thus providing cost savings; and (2) as a second fixed network in a given area, providing a facilities-based fixed network alternative to an FTTx network, thus enhancing competition.

- Wireless also functions in a useful complementary role (1) to provide coverage in low density and/or high cost areas, (2) as a competitive alternative to fixed network solutions, and (3) wherever mobility is needed.

The European Union has committed itself to ambitious Digital Agenda for Europe (DAE) goals. The DAE includes full broadband availability in 2013, 100% availability of 30 Mbps (henceforth called "fast broadband") in 2020, and 50% adoption of 100 Mbps (henceforth called "ultra-fast broadband") by 2020.[2]

The rationale for promoting widespread deployment and adoption of broadband, including ultra-fast (30 Mbps or more) broadband, seems clear enough. Widespread availability of broadband is widely viewed as an important contributor to European economic well-being, and to European competitiveness with other regions including Asia and the United States. One study after another, in Europe and around the world, has shown a range of net benefits for society as a result of the take-up of broadband (see Section 3).

2 See European Commission (2010): "A Digital Agenda for Europe", Brussels, COM(2010) 245, available at: http://ec.europa.eu/information_society/digital-agenda/documents/digital-agenda-communication-en.pdf.

It is widely acknowledged, however, that meeting these DAE goals is extremely challenging. The Commission has estimated the cost to be some € 270 billion,[3] while current consumer incremental willingness to pay for high bandwidth services is estimated at a mere € 5 per month[4] – too little to support so broad a deployment of fibre.

The initial focus of the European institutions and of national governments to date has been largely on deployment of fibre-based NGA – notably Fibre to the Building, and Fibre to the Home, henceforth abbreviated FTTB/FTTH – largely to the exclusion of other high speed broadband capable infrastructure. This focus was arguably excessive, and ran counter to the stated European goal of technological neutrality. More recent statements by the European Commission[5] suggest an increasing recognition of the need for a DAE strategy that acknowledges the potentially complementary role of other technologies.

Against this backdrop, the present study focuses in particular on the actual and potential future role of cable as an infrastructure capable of providing broadband access. The central topic addressed in this study is to what extent cable has the ability to contribute to the objectives of the DAE.

- To what extent should cable be factored into policy planning at national and European level?
- To what extent are mobile and fixed wireless solutions also receiving less attention than they might deserve?

Cable can and does serve (1) as an alternative to making FTTx upgrades, especially in areas where the cost of fibre upgrades would be particularly uneconomic, thus providing cost savings; and (2) as a second fixed network in a given area, providing a facilities-based fixed network alternative to an FTTx network, thus enhancing competition.

The key issues addressed in this study are:

- To what extent is cable coverage available in Europe today?
- What does it cost to upgrade existing cable infrastructure to EuroDOCSIS 3.0?
- To what extent has existing cable already been upgraded for broadband communications purposes? What is the expected time frame in which remaining cable can be expected to be upgraded to EuroDOCSIS 3.0?
- What future evolution can be expected for cable modem broadband technology?

3 http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/11/709&format=HTML&aged=0&language=EN&guiLanguage=en. See also European Investment Bank (2011), “Productivity and growth in Europe; ICT and the e-economy”.

4 Costa Elias, H. (2011): “When and why PPPs are an option for NGA?” EPEC workshop, Caisse des Dépôts, 15 February 2011, available at: http://www.eib.org/epec/resources/presentations/nga-roundtable-costa-elias.pdf.

5 See Chapter 7 of this report.

- In light of the existing coverage, technical capabilities and costs of cable, what are the likely contributions of cable vis-à-vis the DAE objectives and the costs of reaching them?
- What is the current and likely future role of cable broadband as a competitor to telecoms broadband? To what extent do the existence and/or upgrade of cable infrastructure accelerate the deployment of telecoms broadband?

Section 2 reviews the DAE objectives. Section 3 considers the benefits to Europe of achieving DAE objectives. Section 4 reviews the baseline in Europe today: the technologies available for fast and ultra-fast broadband, the geographic and population coverage of existing networks, and the implications of existing coverage for achieving DAE objectives. Section 5 discusses the technological capabilities of a cable network. Section 6 considers the cost of meeting DAE objectives under various mixes of FTTx, cable and wireless technologies. Section 7 considers the issue from the perspective of technological neutrality – why does technological neutrality play such a central role in European regulation, and what are the implications if Europe diverges from technological neutrality in regard to the DAE?

2 KEY GOALS OF THE DIGITAL AGENDA FOR EUROPE (DAE)

Key Findings

Key Findings

- The goals of the Digital Agenda for Europe (DAE) are well known: (1) availability of broadband for all Europeans in 2013, (2) deployment of 30 Mbps broadband capability to all European by 2020, and (3) adoption of 100 Mbps broadband by 50% of European households.
- The detailed meaning of these goals is less clear. What do these speeds really mean, and to what extent must they be reflected in the core network?
- We would propose that the DAE objectives should be interpreted such that networks are designed to provide performance that consumers perceive as acceptable for the applications that they want to run.
- This view argues against a static interpretation of the DAE objectives; rather, the interpretation should track trends in consumer demand for broadband.
- Consumer demand for bandwidth has steadily grown over the last decade, albeit at a percentage rate of growth that is declining over time.
- Bandwidth demand per household is less than many assume, even though total global bandwidth demand is substantial. Per projections based on Cisco VNI data, average global bandwidth demand per household in the busy hour in 2020 is less than 2 Mbps.
- Ultra-fast broadband access is useful, but it is not necessary to assume that every broadband user will consume maximum capacity all the time. The network should assume some shared use of bandwidth. Portions of the network where capacity is shared can be incrementally enhanced as demand grows.
- EuroDOCSIS 3.0 cable systems already comfortably exceed the 100 Mbps called for in the DAE. Even with current technology, cable networks are capable of meeting realistic consumer bandwidth demand well in excess of that which is likely to be present in 2020 and considerably beyond.
- Under reasonable assumptions of technical improvements in cable, cable networks are likely to remain viable for future ultra-fast broadband for extended periods into the future.
- Similar considerations apply to 4G wireless systems. There are surely limitations on the ability of wireless solutions alone to meet DAE objectives in dense population centres, but wireless might play a greater role in low-to-medium density areas than many have assumed.

In this section, we consider the goals of the DAE, a range of seeming ambiguities in the definition of the objectives, and their relationship to the needs of European consumers.

2.1 What are the goals?

European policy would appear, at first sight, to be clear as regards promotion of broadband. The Europe 2020 strategy, and its flagship initiative Digital Agenda for Europe, seek to:

- by 2013, bring basic broadband to all Europeans;
- by 2020, to ensure that all Europeans have access to much higher Internet speeds of above 30 Mbps, and
- by 2020, to ensure that 50% or more of European households subscribe to Internet connections above 100 Mbps.[6]

These goals would seem to be clear, but in fact a great deal of complexity and ambiguity lurks beneath the surface.

2.2 How should the goals be interpreted?

A series of studies by the European Investment Bank appropriately raised the question: What do the bandwidth targets in the DAE signify?

- Do they represent advertised speed, continuously available committed information rate, or something else?
- Should they be interpreted as symmetric bandwidth requirements, or is asymmetry permissible?
- Must the bandwidth be available to all households, or could it be sufficient to serve a smaller number of community locations?
- A question that the EIB did not raise, but that deserves to be raised, has to do with the distribution of the 50% of households that are to subscribe to ultra-fast broadband at speeds of 100 Mbps or more – to what degree might it be acceptable if they were concentrated in urban areas (which are cheaper to serve), or in certain Member States?

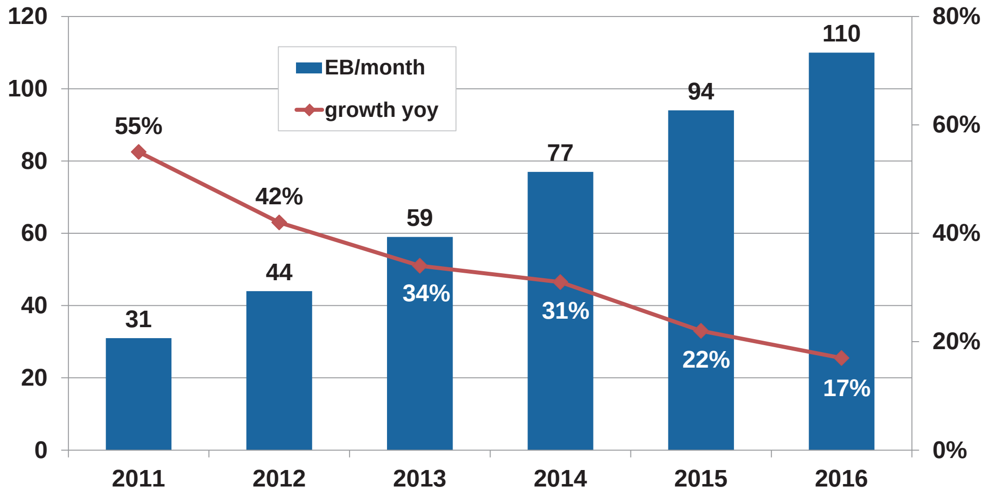
The answers to these questions have quite a strong impact on the cost of network deployment to satisfy DAE goals (see Section 6).

We would put forward the seemingly common sense notion that the *DAE objectives should be interpreted such that networks are designed to provide performance that consumers perceive as acceptable for the applications that they want to run*.

This realisation argues against a static interpretation of the DAE objectives; rather, the interpretation should track trends in consumer demand for broadband. Consumer demand for bandwidth has steadily grown over the last decade, albeit at a percentage rate of growth that is declining over time (see Figure 1), and this trend can be expected to continue. We would argue that the DAE objectives should be interpreted in a manner that tracks this evolution of consumer bandwidth demand over time.

6 DAE, page 19.

Figure 1: Global IT traffic 2011-2016 (Exabytes per month and annual growth rates)



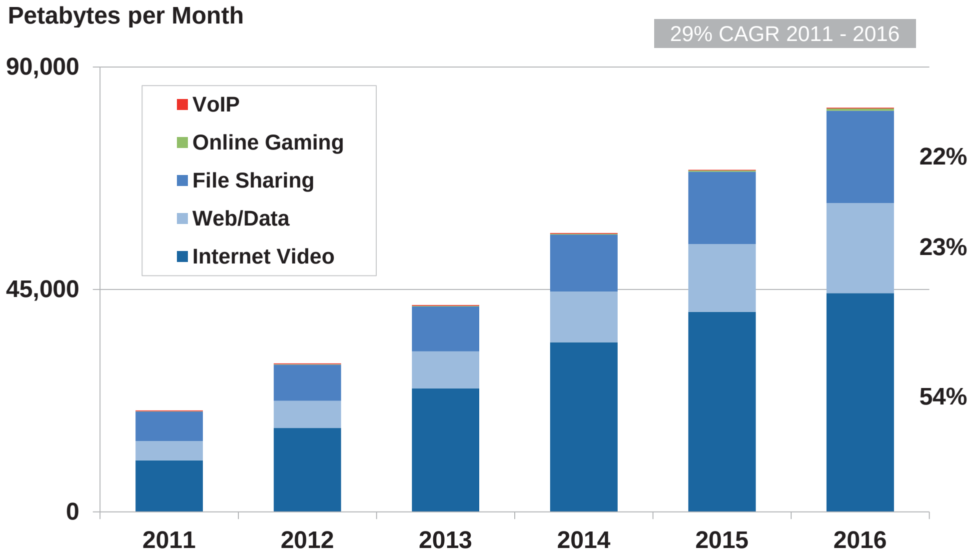
Source: Cisco VNI (2012),[7] WIK calculations.

2.3 What bandwidth do consumers want and need?

What bandwidth are customers likely to want going forward? It is not as difficult as one might think to construct a reasonable estimate. There are numerous projections of the growth in European Internet traffic over time, notably including the annual Cisco *Virtual Networking Index (VNI)*.[8] Cisco analysts compile data from multiple sources in order to estimate current and future Internet traffic by region, by application, and fixed versus mobile (see Figure 2). There is of course uncertainty with any projection of the future, but the Cisco analysis is competent and well respected.

7 Cisco (2012), “The Zettabyte Era” (a part of the Cisco Visual Networking Index (VNI)), white paper, 30 May 2012.
8 Cisco (2012), “The Zettabyte Era”, op. cit.

Figure 2: Global consumer Internet traffic



Source: Cisco VNI (2012).[9]

Internet traffic growth trends in Western Europe are not expected to differ greatly from global trends. Western European IP traffic is forecast to grow at a CAGR of 27% per year over the period, compared to a global CAGR of 29%.[10]

The VNI includes forecasts of traffic per month, and an estimate of the number of households that will consume bandwidth in a given range per month. Even though total demand is enormous, the bandwidth demand of individual households tends to be far less than many have assumed. Moreover, it is clear that even in 2015, a very small fraction of households can be expected to require more than 1,000 GB (which is 1 Terabyte, or 1 TB) per month.

9 Cisco VNI (2012), op. cit.
10 Cisco VNI (2012), op. cit.

Table 1: Internet households by average traffic per month

Number of households by Traffic per Month (Millions of Households)	2010	2011	2012	2013	2014	2015	CAGR
Households generating more than 50 GB per month	62	79	105	126	150	175	23%
Households generating more than 100 GB per month	35	49	61	77	103	125	29%
Households generating more than 200 GB per month	9	19	33	44	58	72	52%
Households generating more than 500 GB per month	3	4	6	8	11	21	48%
Households generating more than 1 TB per month			2	3	5	6	-

Source: Cisco VNI (2011).[11]

Translating the above Cisco data into Mbps demand, during the average hour and during the busy hour, we have the results depicted in Table 2. Data networks are generally designed to carry near-peak traffic; thus, traffic during the busy hour[12] is a good measure of the capacity for which the network must be designed.[13]

11 Cisco VNI (2011a): "Entering the Zettabyte Era", 1 June 2011.

12 We have assumed that peak hour traffic is 1.72 times as great as average traffic per hour, based on the Cisco VNI (2010): "Cisco Visual Networking Index: Usage", 25 October 2010. Peak hour traffic is a reasonable approximation of 95th percentile traffic, depending somewhat on the sampling interval. Per Cisco, the ratio of peak hour traffic to average traffic appears to be slowly increasing over time.

13 Networks cannot be designed for peak traffic because there is no upper bound to the offered load in an IP data network. See J. S. Marcus (1999): "Designing Wide Area Networks and Internetworks: A Practical Guide", Addison Wesley.

Table 2: Average and busy hour global consumer household bandwidth requirements

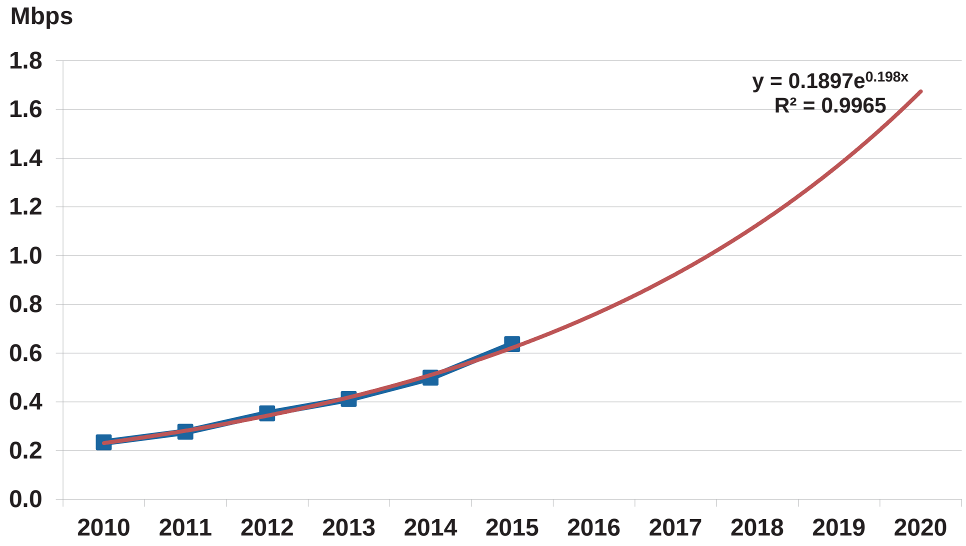
Household generating more per month than GB	Mean BW > Mbps	Busy Hr BW > Mbps	2010	2011	2012	2013	2014	2015
-	-	-	552	555	540	512	465	419
50	0.15	0.27	62	79	105	126	150	175
100	0.31	0.53	35	49	61	77	103	125
200	0.62	1.06	9	19	33	44	58	72
500	1.54	2.65	3	4	6	8	11	21
1,000	3.09	5.31			2	3	5	6

Source: Cisco VNI 2011 data,[14] WIK calculations.

Estimation of the mean aggregate bandwidth demand during the busy hour from the data is straightforward, and is shown in Figure 3. The 2010-2015 figures are based directly on Cisco data, while the 2016-2020 figures are an extrapolation reflecting an exponential regression of the 2010-2015 data. The fit of the regression is very good.

14 Ibid.

Figure 3: The evolution over time of consumer bandwidth demand during the busy hour



Source: Cisco VNI 2011 data,[15] WIK calculations.

What is particularly striking is that the mean global bandwidth demand per household is far less than most have assumed, even though the total is substantial. Even in 2020, the average demand during the busy hour is well below 2 Mbps. This has important implications, as we shall see.

Europe seems to be reasonably well in line with the global trend. The Western European share of total Internet traffic is expected to remain fairly constant over the next five years, while the Central and Eastern European share grows somewhat. On the whole, Europe is not atypical.[16]

2.4 What are the implications of realistic consumer bandwidth demands?

Many policy implications flow from the bandwidth demand characteristics noted in Section 2.3. In this respect, it is important to distinguish between the *access network* (e.g. the last mile) and the *core networks* that connect those access networks to one another and to the world. The policy implications for broadband access networks and for the core networks that support them at national and European level include:

15 Cisco VNI (2011a): “Entering the Zettabyte Era”, 1 June 2011.

16 Cisco VNI (2011b): “Cisco Visual Networking Index: Forecast and Methodology, 2010–2015”.

- Ultra-fast broadband access is useful, but it is not necessary to assume that every broadband user will consume maximum capacity all the time. This can be expected to hold true in 2020 and well beyond.
- The network design can therefore assume some shared use of bandwidth.
- Portions of the network where capacity is shared can be incrementally enhanced as demand grows.
- Different customers will have different bandwidth needs. Different networks will have different customers, and their customers may use their respective networks in different ways (especially fixed versus mobile). All of this argues against a one-size-fits-all approach, and also against a one-technology-fits-all approach. Again, networks should be designed so as to evolve over time to meet the needs of their respective customers.
- EuroDOCSIS 3.0 cable systems already comfortably exceed the 100 Mbps called for in the DAE. Even with current technology, cable networks are capable of meeting realistic consumer bandwidth demand well in excess of that which is likely to be present in 2020, and for that matter in excess of consumer demand that is likely to present considerably beyond 2020. Under reasonable assumptions of technical improvements in cable (see Section 5.3), cable networks are likely to remain viable for future ultra-fast broadband for extended periods into the future.
- Similar considerations apply to 4G wireless systems. Key questions relate to the number of individual users (not households) who must be served by each tower, and the degree to which bandwidth demands differ from those of fixed network users (due, for example, to smaller screen size). There are surely limitations on the ability of wireless solutions alone to meet DAE objectives in dense population centres, but wireless might play a greater role in low-to-medium density areas than many have assumed.

We emphasise that this finding does not *per se* call into question the emphasis that the DAE places on ultra-fast broadband in the access network. Whether *average* consumer bandwidth consumption is low or high, *instantaneous* bandwidth consumption can sometimes be quite high; thus, high speed on the last mile access is beneficial in general.[17] Furthermore, high access speed enables applications and modes of use, notably including high speed video, which would otherwise be unthinkable.

Rather, these considerations argue for an interpretation of DAE requirements that reflects a balanced, technologically agnostic approach that is tailored to the needs of different customer groups, to the different geographic areas in which customers are located, to the capabilities of networks already deployed there, and to the evolution over time of customer needs and of technological capabilities of different transmission media.

17 This follows from the basic mathematics (queuing theory) that governs network performance. See J. S. Marcus (1999).

3 POTENTIAL BENEFITS OF BROADBAND IN EUROPE

Key Findings

Key Findings

- ► The various studies on the value of broadband consistently find significant benefits from broadband deployment and adoption.
- ► There is considerable uncertainty, however, over the degree to which greater broadband speed produces greater benefits.
- ► Some suggest that there may be a tendency for incremental benefits to be subject to diminishing returns as broadband penetration approaches saturation.
- ► An interesting recent study on behalf of the OECD might suggest that broadband benefits, measured by consumer Willingness to Pay (WTP) for broadband, may be greater in countries where competition is more effective.
- ► Caution is appropriate in interpreting any of these results.

The benefits of broadband are widely accepted, but a few words on this subject are perhaps in order.

There are many different ways in which one could attempt to measure the societal benefits to *consumers* and *producers*. Consumers benefit, for instance, by being able to do things that they were not previously able to do (e.g. with slow dial-up Internet access), or by being able to accomplish more per unit time. Among producers, network operators benefit by selling broadband to consumers, network equipment manufacturers benefit by selling equipment to network operators, and providers of Internet applications, services and content benefit by selling services to consumers or by selling advertising to a wide range of firms. The sum of these consumer and producer benefits, and many more, can in principle be added to provide the gain in societal welfare; however, that sum must be computed net of relevant costs.

3.1 Assessments of the benefits of broadband

Numerous studies have been conducted on the benefits of broadband that we have highlighted in the previous sections of this report. Nonetheless it is useful to summarise our views on a few of the more relevant findings.

- The various studies on the value of broadband consistently find significant benefits from broadband deployment and adoption. They do not necessarily agree on the level of benefits.
- There is considerable uncertainty, however, over the degree to which greater broadband speed produces greater benefits.

- Some suggest that there may be a tendency for incremental benefits to be subject to diminishing returns as broadband penetration approaches saturation.
- Caution is appropriate in interpreting any of these results.

Czernich et al. found that a 10% increase in broadband penetration results in an increase in GDP growth of between 0.9% and 1.5%.[18]

Koutroumpis's study of 22 OECD countries yields, however, much lower results: he found that an increase in broadband penetration of 10% yields only a 0.25% increase in economic growth.[19]

A study by Micus Management Consulting and WIK-Consult[20] suggests that companies adopting broadband-based processes improve their employees' labour productivity by 5% on average in the manufacturing sector, and by 10% in the services sector.

Thompson and Garbacz[21] found that an increase in broadband penetration produces macroeconomic benefits.

Liebenau et al. (2009)[22] find that an additional £5 billion investment in broadband networks would create or retain an estimated 280,500 UK jobs for a year.

In a sophisticated study drawing on data from more than 6,000 New Zealand businesses, Grimes et al. (2009)[23] found a "… productivity effect of broadband relative to no broadband of approximately 10% across all firms. The estimates indicate a marginally stronger impact on firm productivity for firms in rural (low population density) relative to urban (high density) areas but the differences are not significantly different." These results are consistent with the other studies already noted.

Grimes et al. go on however to note: "Our estimates show that all of these productivity gains can be attributed to adoption of slow relative to no broadband, with no discernible additional effect arising from a shift from slow to fast broadband." In this study, fast broadband is defined as being above 10Mbps.

Grimes et al. is one of the few studies that attempts to assess the incremental benefits of fast or ultra-fast broadband compared to slow or conventional broadband. A more comprehensive study dealing with these issues was conducted on behalf of the European Commission by Analysys Mason. They found substantial incremental benefits from ultra-fast broadband (see Section 3.3).

18 See Czernich, N., Falck, O., Kretschmer, T. and L. Woessmann (2009): "Broadband Infrastructure and Economic Growth"; CESIFO Working paper no. 2861; Munich; December.

19 See Koutroumpis, P. (2009). "The Economic Impact of Broadband on Growth: A Simultaneous Approach"; in: Telecommunications Policy, vol. 33; P. 471-485.

20 See Fornefeld, M., Delauney, G. and D. Elixmann (2008): "The impact of broadband on growth and productivity"; A study on behalf of the European Commission (DG Information Society and Media).

21 Thompson, H. and C. Garbacz (2008): "Broadband ímpacts on State GDP: Direct and indirect impacts"; paper presented at the International Telecommunications Society 17th Biennial Conference, Montreal, Canada.

22 See Liebenau, J., Atkinson, R., Kärrberg, P., Castro, D. and S. Ezell: (2009): "The UK's Digital Road to Recovery"; LSE Enterprise ltd. & The Information Technology and Innovation Foundation; April.

23 Grimes, A., Ren, C. and P. Stevens (2009): "The need for speed: Impacts of Internet connectivity on irm productivity"; Motu Working Paper 09-15; Motu Economic and Public Policy Research, October; available at: http://motu-www.motu.org.nz/wpapers/09_15.pdf.

The impact of greater broadband speed is closely linked to the benefits of increasing penetration. Lehr et al.[24] argue that the benefits of broadband adoption may diminish as broadband penetration rises. Howell and Grimes (2010)[25] argue that diminishing returns could be seen as a typical result from the diffusion of a technology where the early adopters are those who value the service most highly (and presumably benefit from it the most), and the later adopters ("laggards") are those who value the service the least. Key questions are the degree to which higher broadband speeds lead to (1) the development of new applications in response to fast or ultra-fast broadband, and (2) the take-up of fast or ultra-fast broadband by new users. Howell and Grimes (2010), however, argue that fast or ultra-fast broadband has not stimulated much new application development to date, and that fast broadband users are most likely to be existing broadband users who are upgrading to faster broadband. The authors therefore underscore that, as faster broadband becomes more widely deployed, it would also be most likely that similar decreasing returns would be observed on the faster networks as well.

Crandall et al. (2007)[26] argue that the correlations with broadband deployment and adoption do not necessarily imply that broadband causes societal benefits; it might just as well be the case that societies with high GDP and high efficiency are more amenable to rapid deployment and adoption of broadband. In other words, the correlations identified in the various studies do not necessarily tell us which causes which.

In sum, while there is disagreement over the magnitude of benefits, and over the degree to which ultra-fast broadband generates *additional* benefits compared with conventional broadband, there is widespread agreement that broadband adoption generates substantial societal benefits.

3.2 Consumer Willingness to Pay as a measure of benefits

One recent study (conducted by Greenstein and McDevitt on behalf of the OECD)[27] has attempted to estimate the gains in consumer surplus by assuming that the consumer initially subscribes to broadband at the moment at which the consumer perceives the value of broadband as being equal to the price that the consumer must pay. At that instant, perceived costs and benefits can be assumed to be in balance, in which case there is no surplus. Perceived benefits cannot be less than the cost, otherwise the consumer would not have made the purchase. The consumer's willingness to pay (WTP) is thus a measure of the consumer's estimate of the benefit that he or she expects to derive.

24 Lehr, W., Osorio, C., Gillett, S. and M. Sirbu (2006): "Measuring broadband's economic impact"; paper presented at the 33rd Research Conference on Communication, Information, and Internet Policy (TPRC), Arlington, Virginia, September 23-25; 2005; revised January 17, 2006.

25 Howell, B. and A. Grimes (2010): "Feeding a need for speed or funding a fibre 'arms race'? Productivity questions for FTTH network financiers"; April; available at http://www.iscr.co.nz/f563,16240/16240_Feeding_a_Need_for_Speed_v4.pdf.

26 Crandall, R., Lehr, W. and R. Litan (2007): "The effects of broadband deployment on output and employment: a cross-sectional analysis of U. S. data"; in: Issues in Economic Policy no. 6, The Brookings Institute, July.

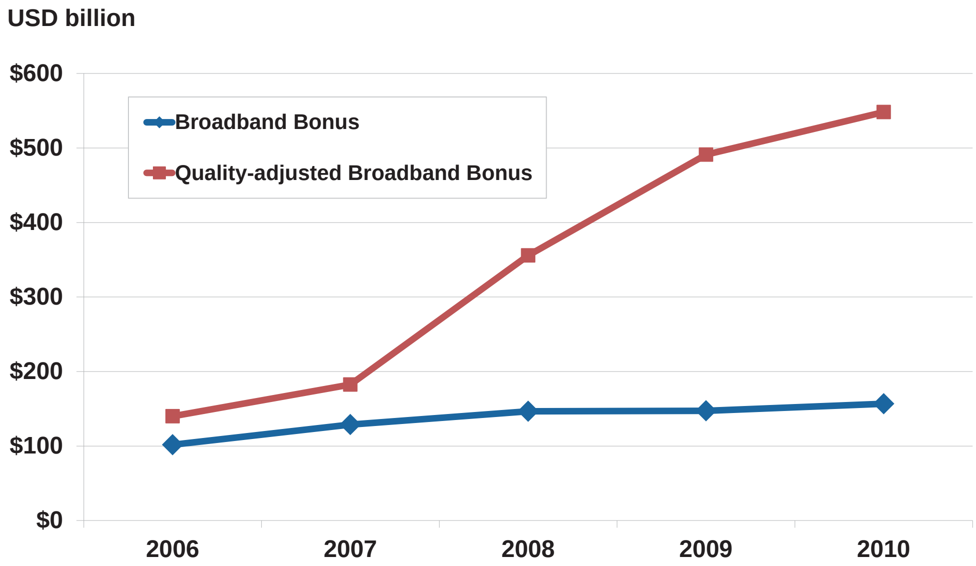
27 Greenstein, S. and R. McDevitt (2012), "Measuring the Broadband Bonus in Thirty OECD Countries", OECD Digital Economy Papers, No. 197, OECD Publishing. http://dx.doi.org/10.1787/5k9bcwkg3hwf-en.

To the extent that the price of broadband subsequently declines,[28] or that the quality (e.g. available bandwidth) provided at the same price increases, or that new applications become available over the broadband connection, the consumer derives additional benefits or *surplus*.

As Greenstein and McDevitt note, this estimate of surplus is probably conservative, even though it implicitly recognises a number of net benefits that tended to be ignored in previous work.

These results (depicted in Figure 4) show that, over the OECD as a whole, quite substantial aggregate levels of surplus are visible. Europe is a major beneficiary of this surplus, inasmuch as Europe represents a large proportion of OECD members and a significant fraction of the relevant population and GDP.

Figure 4: The "broadband bonus" in the OECD countries



Source: Greenstein and McDevitt (2012).

The Greenstein/McDevitt analysis of surplus at national level is interesting, but not altogether unambiguous. Countries with large Internet economies, including the United States, Japan and Germany, are receiving large benefits from broadband. A comparison of the absolute magnitude of the surplus tends to blur comparison, however, since countries with larger GDP or larger population would be favoured.

28 Greenstein and McDevitt base their analysis on OECD retail broadband prices as published in Tables 7.17 and 7.18 in the OECD Communications Outlook 2011, multiplied by the estimated subscribers by access type. There are methodological challenges in this approach, but we will not deal with them here since they will be obvious to the experts and uninteresting to other readers.

When viewed on a basis normalised for GDP or for the number of broadband users, it becomes clear that some of the obvious front-runner countries have done extremely well, including the Netherlands, Switzerland, and Belgium. These are all, not coincidentally, countries with substantial competition between the fixed telecommunications network and cable. Hungary, where cable competition is strong, also does quite well by this measure. At the same time, countries where cable is absent do not necessarily perform poorly, while the United States (where the market has been split about 55%/45% between cable and telecommunications for years) does not do conspicuously well. It may well be that these differences in broadband surplus are primarily a function of the level of competition. A strong cable presence contributes strongly to competition; however, competition may be weaker than otherwise expected for other reasons (for example, an institutionally weak regulatory system), or stronger than otherwise expected due to effective use of competitive remedies such as *unbundled local loop (ULL)*.

3.3 Benefits of ultra-fast broadband

As previously noted, most studies of the benefits of broadband do not distinguish between conventional broadband (at speeds of less than, say, 10 Mbps) and ultra-fast broadband at speeds of 30 Mbps or greater. A notable exception is a study that Analysys Mason and tech4i2 completed on behalf of the European Commission.[29] The report has not yet been publicly released; however, preliminary results have been presented publicly.[30]

One part of the Analysys Mason study deals with an empirical assessment of the socio-economic impact of high-speed broadband investment in Europe. To this end, three main indicators were calculated:

- Input-output impact,
- Return on investment (ROI), and
- Cumulative impact on GDP.

Table 3: Impacts of high speed broadband investment in Europe 2012-2020

	Expenditure (EUR bn)	Expenditure per head (EUR)	I/O benefit (EUR bn)	ROI	Cumulative impact on GDP
EU27	220	436	485	2.2	2.0%

Source: Yardley et al. (2012a); slide 82.

29 See Yardley et al. (2012a). The analysis done by Analysys Mason and tech4i2 is based on an input-output model which takes into account the respective investment expenditures for electronic equipment, construction and telecoms.

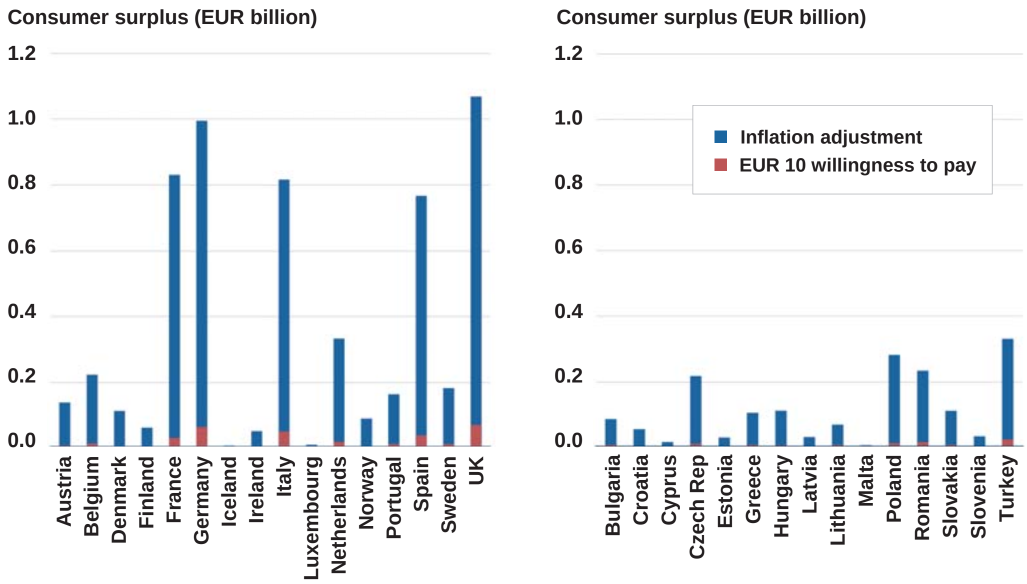
30 Intermediate results were presented at a public workshop in Brussels in February 2012. We understand that these results differ in some important respects from the final results of the study.

The table shows that for the EU 27 countries, the overall expenditures are estimated at € 220 billion, corresponding to an expenditure of € 436 per head. These expenditures lead to an overall Input-Output benefit of € 485 billion, thus corresponding to a return on investment (ROI) of 2.2. The cumulative impact on GDP is estimated to be 2.0%.

The study has also addressed the issue of consumer surplus, i.e. the gains that consumers experience because their willingness to pay (WTP) for a good or service is greater than the actual price they are obliged to pay for the good or service.

Analysys Mason and tech4i2 expect the average 2020 high speed access price in Europe to be € 22.61, which is 78.2% of the value in 2010. If inflation is taken into account, the expected average price for ultra-fast broadband access in 2020 is estimated to be 61.8% of the cost in 2010. Figure 5 shows the results of the consumer surplus estimates for the Western European and Eastern European EU 27 Member States (plus Iceland, Norway, Croatia, and Turkey) assuming an incremental willingness to pay of 10 Euro for ultra-fast Internet access,[31] and taking inflation into account.

Figure 5: Consumer surplus in Europe (bn. Euro)



Source: Based on Yardley et al. (2012a); slide 86.

Figure 5 shows that consumer surplus is far less than one billion Euro in most Member States (exceptions are Germany where it is equal to about 1 bn. Euro and the UK, where it is slightly higher than 1 bn. Euro). Moreover, the figure shows that the aggregate consumer surplus in the EU 27 countries is much lower than the estimated input-output benefit.

31 See Rosston, G., Savage, S. J. and D. M. Waldman (2010): Household Demand for Broadband Internet Service; Final report to the Broadband.gov Task Force, Federal Communications Commission; 3 February 2010.

4 THE BASELINE TODAY: BROADBAND COVERAGE

Key Findings

Key Findings

- There are many different technologies that could be used to meet DAE objectives, notably including the fixed telecommunications network, but also including cable television, as well as fixed and mobile wireless services.

- In assessing the current status, it is important to distinguish between the *coverage* or *deployment* of each technology, versus *adoption* (i.e. the degree to which consumers choose to subscribe to the service).

- Each technological platform is benefitting in many ways from technological enhancements over time.
  - The maximum speed of fibre-based FTTC/VDSL systems could benefit from vectoring, and to a lesser extent from pair bonding and phantom DSL.
  - Cable systems benefit in the near term from progressive deployment of EuroDOCSIS 3.0 technology, from the bonding of more channels together under EuroDOCSIS 3.0, from driving fibre deeper into the cable network, and potentially in the longer term from a reallocation of frequencies on the cable (see Chapter 5).
  - Wireless systems benefit from deployment of LTE, and eventually from the deployment of LTE-Advanced.

- The relative cost of achieving each of the DAE objectives with each of these technologies can vary greatly (see Chapter 6). Those costs depend to a significant degree on the coverage footprint of the technology.
  - For the fixed telecommunications network, there are significant uncertainties as to the quality of currently available data. A study that has been conducted on behalf of the European Commission will hopefully provide clarity.
  - For cable, large portions of Europe have already been upgraded to EuroDOCSIS 3.0. Within the 2020 DAE planning horizon, substantially all European cable will have been upgraded to EuroDOCSIS 3.0 (if not to a successor).
  - For wireless broadband, the footprint of LTE and LTE-Advanced can be expected to be at least as broad in 2020 as that of 2G and 3G networks today.

- Achievement of full broadband coverage (and especially of ultra-fast broadband) in Europe is complicated by (1) variations in population density from region to region; (2) challenging topography in portions of Europe; and (3) possibly by gaps in coverage of the fixed network in parts of Eastern Europe.

- Achievement of the DAE objectives for deployment and adoption of ultra-fast broadband is further complicated by an apparent gap between the cost of deployment, and the maximum price that consumers are willing to pay. Multiple studies, including a recent WIK study of Germany that is summarised here, suggest that full achievement based solely on fibre-based telecommunications solutions is unlikely without some degree of public policy intervention and/or subsidy.
- Factoring cable broadband and wireless broadband into the analysis can help significantly to close this gap (as we shall demonstrate in Chapter 6); however, the effects will vary among the Member States, in part as a function of the degree of coverage of the cable television network.

In this chapter, we consider the situation on the ground today in Europe, and its implications for DAE deployment. In doing so, it is important to distinguish between the *coverage* or *deployment* of each technology, versus *adoption* (i.e. the degree to which consumers choose to subscribe to the service). It is almost important to bear in mind that a given area can be served by more than one technology, and that a given consumer may be served by more than one DAE-compliant service (e.g. both fixed and mobile).

Since our objective here is to understand the implications for meeting DAE goals, including 30 Mbps deployment and 100 Mbps adoption, it is necessary to begin with a discussion of capabilities of the broadband technologies that are likely to be suitable for meeting those DAE goals in 2020 (Section 4.1). This leads into a discussion of the current cost of deploying each of these technologies. It is important to note that *incremental* costs of deployment are primarily of interest here, not total costs or forward-looking costs – this is not a regulatory, greenfield modelling exercise.

We then consider the footprint for each technology today (see Section 4.2).

We continue and conclude with a discussion of the challenges to achieving full deployment of conventional broadband (Section 4.3) and of ultra-fast broadband at 30 Mbps and 100 Mbps (Section 4.4).

4.1 Technologies for fast broadband

Some have attempted to limit the discussion of *Next Generation Access (NGA)* in the context of the Digital Agenda for Europe to fibre-based solutions; however, modern *Hybrid Fibre Coaxial (HFC)* cable-based solutions obviously deliver capabilities that are functionally equivalent to telecom fibre-based NGA today. Fixed and mobile wireless solutions also deliver capabilities that are relevant to the DAE, and rapidly improving. It is thus useful at this point to briefly put these diverse technologies in perspective.

4.1.1 Fibre-based solutions

The local loop of a traditional telephony network covers the network part between the main distribution frames (MDF) and the end users. The “nodes” in this local loop are the street cabinets. The traditional local loop is entirely based on copper infrastructure. Overall, there are three main fibre based solutions for the local loop:[32]

- **Fibre to the cabinet (FTTC) in connection with a VDSL solution**: The copper network between MDF and cabinet is replaced by fibre and VDSL multiplexers are installed at the cabinet; the copper network between cabinet and end user, however, remains unchanged. FTTC/VDSL technologies are very distance sensitive; they are able to deliver 50 Mbps provided the copper sub-loop is shorter than about 400-500 meters. Recent developments (bonding, vectoring, and phantoming) are, however, squeezing more bandwidth out of the copper part of a FTTC/VDSL network. Vectoring focuses on the cancellation of noise, as cross talk is the dominant disturber for VDSL.[33] VDSL2 bonding typically combines two regular VDSL2 lines into a single, virtual “big pipe” that allows operators to double the bit rate for existing subscribers.[34] DSL Phantom Mode involves the creation of a virtual or “phantom” channel that supplements the standard configuration for copper transmission lines.[35]

- **Fibre to the building (FTTB):** The copper network between MDF and the building is replaced by fibre; the “in-house cabling” still rests on copper; the optical/electrical interface can be installed outside (e.g. at the surface of) or inside (e.g. in the basement of) the building. The in-house transmission might rest on VDSL technology.

- **Fibre to the home (FTTH):** The complete local loop including the in-house wiring is based on fibre optic technology. In a Multiple Dwelling Unit (MDU), each home has a fibre access.[36]

Depending on the specific architectural and topological features, an FTTB/H infrastructure can deliver far higher bit rates than FTTC/VDSL technologies.

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32 More detailed information can be found e.g. in Neumann, K.-H., Schäfer, R.G., Doose, A.M. and D. Elixmann (2011): Study on the Implementation of the existing Broadband Guidelines Final Report DG Competition; December 7; available at: http://ec. europa.eu/competition/consultations/2011_broadband_guidelines/index_en.html

33 Vectoring has the potential for very significant bit rate increase, however, the potential gain is significantly reduced if there is only a partial control over all VDSL2 lines e.g. due to unbundling (LLU/SLU), see van der Putten (2011): Alcatel-Lucent antwoord op Ontwerpbesluit van de Raad van het BIPT van 20 December 2010 betreffende de Analyse van de Breedbandmarkten 18 Februari.

34 Alternatively, it allows them to deliver the same bitrates over longer distances.

35 Bonding and phantoming, thus, require an infrastructure based on twisted pair copper lines.

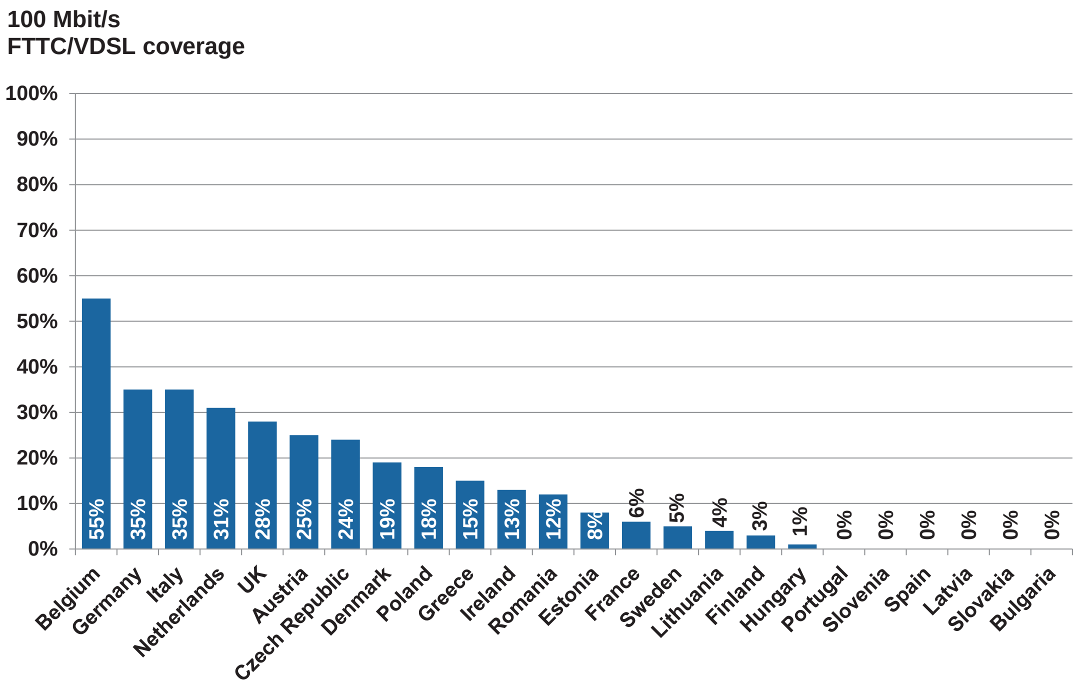
36 In a Gigabit Passive Optical Network (GPON), the typical bandwidth is up to 2.5 Gbps downstream and up to 1,25 Gbps upstream. In a GPON system, however, the bandwidth is shared by all users connected to a given splitter. Current implementations are based on splitting ratios of 1:32 or 1:64. By contrast, a Point-to-Point fibre architecture is based on dedicated fibre strands for each customer, i.e. the total fibre capacity is available for each distinct customer.

Many have consequently assumed that FTTC/VDSL is relevant to 30 Mbps DAE objectives, but no more; however, this ignores the *second life of copper*. The second life of copper entails the use of new technologies, including *vectoring* (based on advanced noise cancellation), *pair bonding* (which relies on a second copper pair being available), and *phantom mode* (an exotic further extension of pair bonding). As the Austrian NRA (the RTR) recently observed, "… the potential to achieve higher bandwidths in the copper network is far from being exhausted. New technologies like vectoring or phantom mode may increase achievable bandwidths to 100 Mbit/s or above. These technologies are still in development, but can be expected to be employed commercially soon. They could therefore make a significant contribution to achieve the goals of the Digital Agenda for Europe."[37]

The degree to which these technologies will be viable in practice is not altogether clear. Pair bonding and phantom DSL, for instance, are relevant only where a second pair is available.

In a recent study, Analysys Mason estimated that a substantial fraction of European households are accessed over sub-loops of less than 400 meters, in which case 100 Mbps should be achievable.[38]

Figure 6: Predicted 100 Mbps FTTC/VDSL European household coverage in 2020



Source: Yardley et al. (2012b).

37 See RTR, "Consultation input from RTR GmbH (Austrian Regulatory authority for broadcasting and telecommunications)", input to " European Commission Consultation on costing methodologies for key wholesale access prices in electronic communications", November 2011.

38 See Yardley, M. et al. (2012b): "Policy orientations to reach the European Digital Agenda targets", Analysys Mason, 23 May.

4.1.2 Cable solutions

Unlike the traditional cable infrastructure optimised for handling broadcast television programmes, modern Hybrid Fibre Coaxial (HFC) cable solutions are capable of simultaneously carrying voice, data and video services. In a nutshell, the key elements of a cable network are[39] one or more master headend(s) (together with a Network Operation Center and a specific backbone network), regional headends (together with regional backbones), central intelligence facilities (Cable Modem Termination Systems, CMTS), optical nodes (fibre hubs) defining a specific cable cluster of customers, and trunk and line amplifiers (reflecting attenuation) within each cable cluster. The physical transmission links between CMTS and end users comprise fibre and copper (coaxial) infrastructure (Hybrid Fibre Coaxial, HFC). A CMTS administers several fibre nodes linked to the CMTS via a fibre ring, and each of these fibre nodes is linked to the end users via copper based lines. Cable networks can offer Gigabit bitrates for IP traffic. The customers within a given cable cluster, however, share this capacity.[40]

We discuss cable capabilities at length in Section 5.

4.1.3 Wireless solutions

Wireless solutions based on Orthogonal Frequency Domain Multiplexed (OFDM) technologies such as LTE or WiMAX are becoming progressively more capable over time, but they are sometimes ignored in discussions of the DAE because they are felt to be too slow.

Feijoo et al. (2011a) argue persuasively that wireless solutions merit serious consideration, not only as a means of achieving conventional broadband penetration, but also as a vehicle for ultra-fast broadband going forward. “First, some new technologies are approaching the 100 Mb/s threshold, at least with regard to peak data rates. Second, these technologies are also arguably the only viable solution for rural and remote areas with very low population density. Last but not least, the advantages of ubiquitous broadband access for customers are considerable and they could well compensate for lower guaranteed speeds.”[41] One might well add that mobility offers advantages of its own.

In the European Union’s *Radio Spectrum Policy Programme (RSPP)*, this is explicitly reflected in Recital 4: “[The RSPP] is also a key action in the Digital Agenda for Europe which aims to deliver fast broadband internet in the future network-based knowledge economy, with an ambitious target for universal broadband coverage with speeds of at least 30 Mbps for all Europeans by 2020.”

39 See Chapter 5 for more details.

40 Apart from the very different physical infrastructure, an HFC cable system is broadly comparable to a GPON fibre system. In the cable system, the customers in a given cable cluster share the available capacity, while in a GPON system this is the case for the customers connected to a given splitter.

41 Feijoo, C., Gómez-Barroso, J.-L., Ramos, S. and R. Coomonte (2011a): “The Mobile Communications Role in Next Generation Networks: The Case of Spain”, 22nd European Regional ITS Conference, Budapest, 18-21 September 2011.

The Radio Spectrum Policy Group (RSPG) has also looked at the issue, and observed: "[The RSPP] is also a key action in the Digital Agenda for Europe which aims to deliver fast broadband internet in the future network-based knowledge economy, with an ambitious target for universal broadband coverage with speeds of at least 30 Mbps for all Europeans by 2020."[42]

Steady technological improvements are noteworthy. The migration to LTE, and then to LTE Advanced, represents a substantial increase in the nominal speed of wireless data transmission, and also in efficiency in terms of bits per Hertz. Typical realistically achievable speeds are less than those that are theoretically achievable, but are nonetheless impressive. Efficiency gains come through the use of multiple antennae (MIMO), and simply from making more spectrum available.

Table 4: Typical maximum achievable speeds for various wireless solutions

Mobile technology	Range of typically achievable maximum downstream bandwidth (Mbit/s)
HSPA	2-5
HSPA+	5-25
LTE	10-100

Source: TNO/WIK.[43]

As we explain in Section 4.2.4, wireless coverage is widespread in Europe today, and by 2020 (the target date for the second and third DAE objectives) it can confidently be expected that substantially all wireless infrastructure in Europe will have been upgraded to either LTE or LTE Advanced.

42 RSPG, "RSPG Report on Improving Broadband Coverage", RSPG11-393 Final, 16 November 2011.

43 Nooren, P. J., Marcus, J. S. and I. Philbeck (2012): "State-of-the-Art Mobile Internet connectivity and its Impact on e-commerce", presentation to the IMCO Committee of the European Parliament, 28 June 2012, WIK and TNO, available at: http://www.europarl.europa.eu/document/activities/cont/201206/20120628ATT47917/20120628ATT47917EN.pdf.

4.1.4 Relative costs of different technologies

Much of the analysis of NGA or DAE deployment has been limited to fibre, but a few papers have considered the relative costs of fibre, cable and wireless in a more integrated and holistic way. One of these is Hätönen (2011),[44] which is discussed in depth in Section 6. Another contribution is a series of papers by Feijoo and Barroso.[45]

In understanding the costs of deployment, it is helpful to first understand the coverage of fixed and cable networks today, and the population distribution of Europe.

4.2 The coverage footprint today

In considering the cost of meeting all three of the DAE objectives, it is important to understand the coverage footprint of fixed networks and cable networks in the European Union today.

4.2.1 Uncertainties in current coverage statistics

The European Commission has sponsored studies of broadband coverage, primarily ADSL coverage, for many years.[46] These data have been reflected in a range of Commission studies, and have been picked up without question in other studies such as those of the EIB.

Past Commission estimates of DSL coverage have assumed that the fraction of *Main Distribution Frames (MDFs)* that contain a *Digital Subscriber Line Access Multiplexer (DSLAM)*[47] is a suitable measure of coverage. This tacitly assumes (1) that existing lines from the MDFs extend to reach all households, and (2) that all existing lines are potentially suitable for DSL.[48] We suspect that these estimates did not place sufficient weight on limitations in fixed network deployment in newer Member States. If these estimates are overly optimistic, then most estimates of the cost of achieving DAE objectives could be in error, even for the first DAE objective (basic broadband for all Europeans by 2013). The cost of achieving each of the three DAE objectives by means of the copper or fibre telecommunications lines is heavily dependent on upgrading the existing fixed network, which in turn depends on the coverage footprint.

44 Hätönen, J. (2011): "The economic impact of fixed and mobile high-speed networks", European Investment Bank (EIB).

45 See Feijóo, C., and J.-L. Gómez-Barroso (2010a): "A Prospective Analysis of the Deployment of Next Generation Access Networks: Looking for the Limits of Market Action: The Case of Spain", report for NEREC; Feijóo, C., Gómez-Barroso, J.-L., Ramos, S. and R. Coomonte (2011b): "Dynamics of Broadband Markets in Europe: The Case Study of Spain"; and Feijóo, C., Gómez-Barroso, J.-L., Ramos, S. and R. Coomonte (2011a): "The Mobile Communications Role in Next Generation Networks: The Case of Spain", op. cit.

46 See IDATE (2011), Broadband Coverage in Europe, Final Report, 2011 Survey Data as of 31 December 2010, 2011, at http://ec.europa.eu/information_society/digital-agenda/scoreboard/docs/pillar/broadband_coverage_2010.pdf.

47 A DSLAM is a network device that is commonly provided by telecommunications operators. It connects multiple customer digital subscriber lines to the network.

48 Corrections for fixed network coverage were made in Poland and the Czech Republic, but apparently not in all Member States. Line length adjustments were made, but again not in all Member States.

The firm Point Topic is conducting an ongoing survey of broadband coverage on behalf of the Commission. The methodology should potentially be more robust than that which was used in prior years. The study was expected to be published in June 2012, but has been delayed. We would not be surprised if it results in revisions to Commission estimates of coverage, and thus of the cost of achieving the DAE.

4.2.2 Coverage of telecoms networks

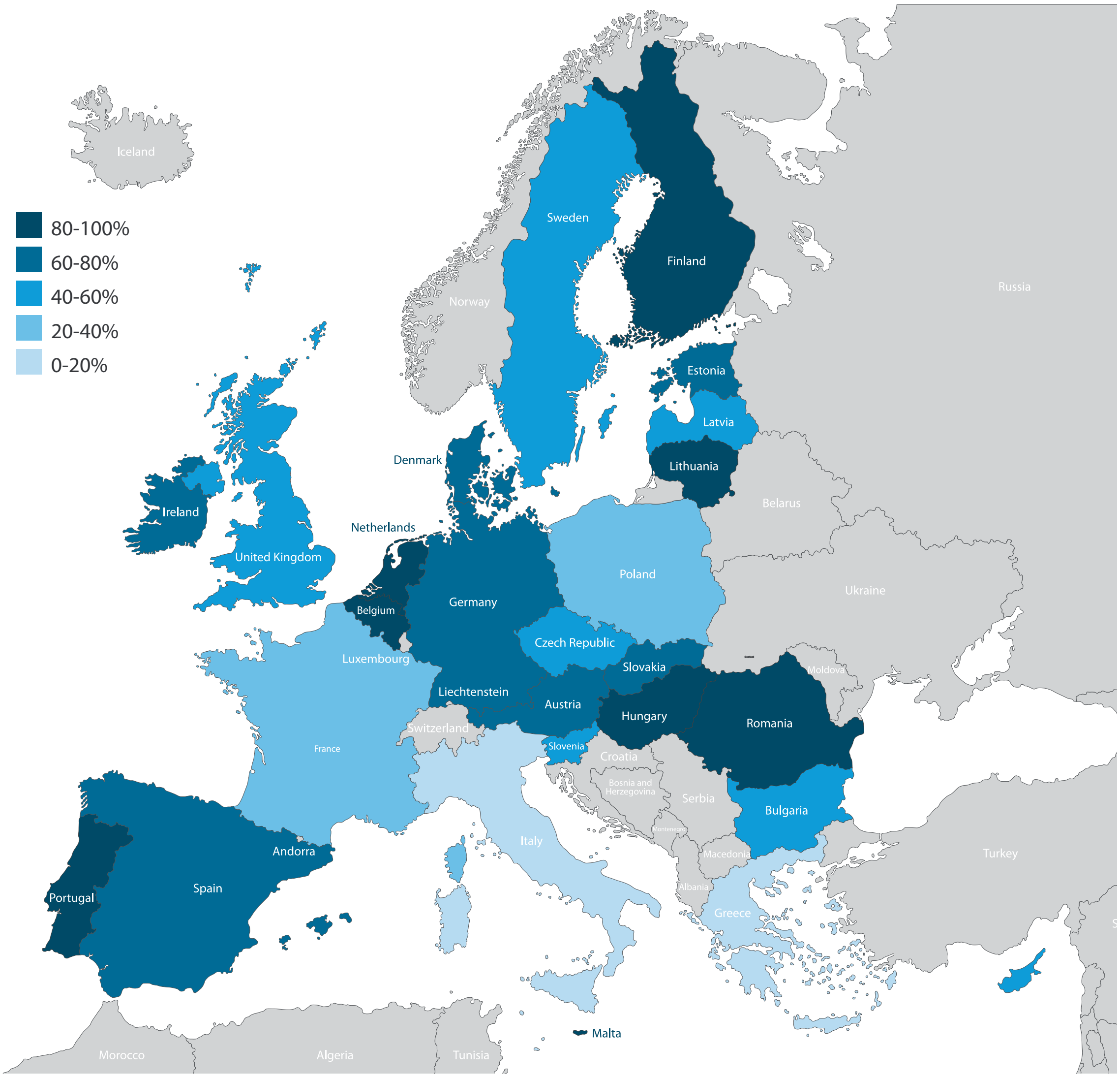
In the Western European EU-15 Member States, we believe that the coverage of the fixed telephony network is more or less complete. In some of the newer Member States in the east, coverage of the fixed telephony network might well be less than 100% of households passed. As noted in Section 4.2.1, the firm Point Topic is conducting a detailed survey for the Commission that will hopefully shed light on the issue; however, the results have not yet been published. We look forward to seeing these new coverage statistics once they become available.

There are also differences from one Member State to the next in the distance of the household from the Main Distribution Frame (MDF) and from the street cabinet, differences in the quality of copper loops, and differences in the presence or absence of ducts. These aspects have different impacts on deployment costs and on the capabilities of deployed services for different kinds of conventional and ultra-fast broadband. Since these complex issues are covered at length in many other studies, we will not dwell on them here.

4.2.3 Coverage of cable networks

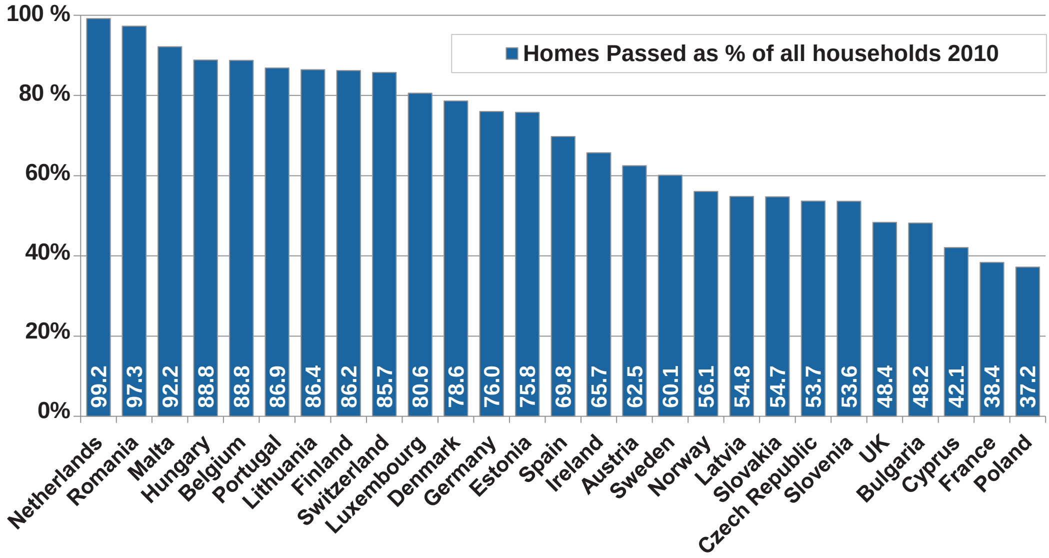
Some 55% of all households in the EU are reachable by cable television, but the distribution is highly variable among the Member States. Italy and Greece have negligible cable television, while coverage is in excess of 85% in the Netherlands, Romania, Malta, Lithuania, Belgium, Hungary, and also in non-EU member Switzerland.

Figure 7: Percentage of households passed by cable (2010)



Source: Screen Digest (2010), WIK calculations.

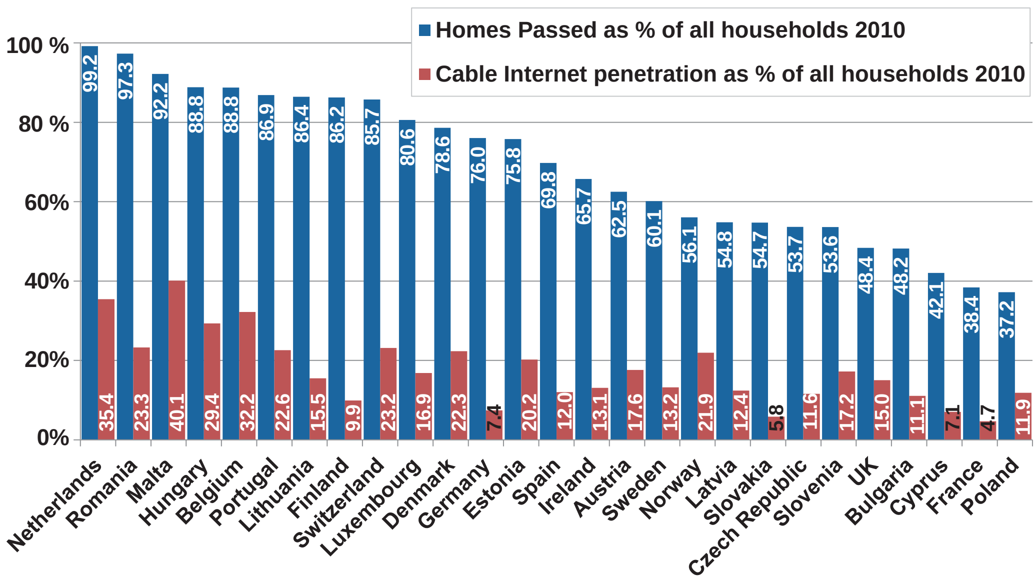
Figure 8: Percentage of homes passed by cable per Member State



Source: Screen Digest (2011).

Meanwhile, the “gap” between cable coverage and cable broadband penetration represents a significant opportunity for Europe and for the industry.

Figure 9: Homes passed by cable versus cable broadband adoption, by Member State



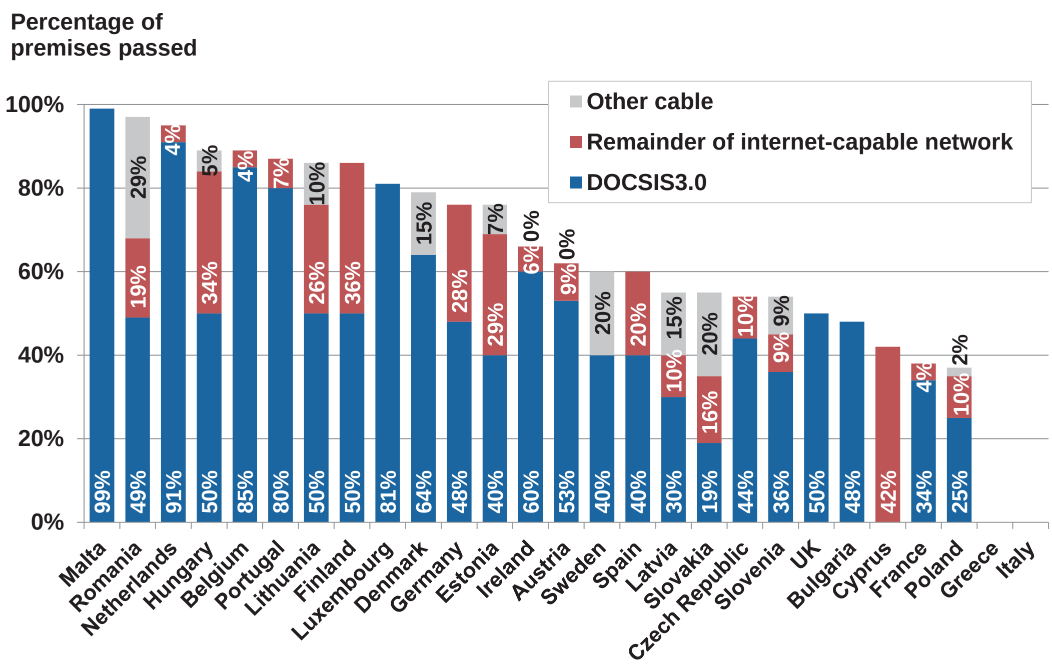
Source: Screen Digest (2011), WIK calculations.

We have done a detailed analysis of the Liberty Global coverage footprint. It is clear that Liberty Global´s cable coverage in Europe is substantial, and that 94% of Liberty Global´s cable has already been upgraded to modern EuroDOCSIS 3.0; however, the degree of coverage and the degree to which cable has been upgraded varies somewhat by Member State and by cable network operator.

Well in advance of 2020, the target year for the ultra-fast broadband targets, we expect that substantially all European cable will have been upgraded to EuroDOCSIS 3.0 (or perhaps to its successor).

This is consistent with findings in a recent study by Analysys Mason, which found that a large portion of cable has already been upgraded to DOCSIS 3.0 (see Figure 10).

Figure 10: Estimated coverage of cable and of DOCSIS 3.0 in Europe, 4Q2011



Source: Yardley et al. (2012b).

4.2.4 The potential for wireless solutions

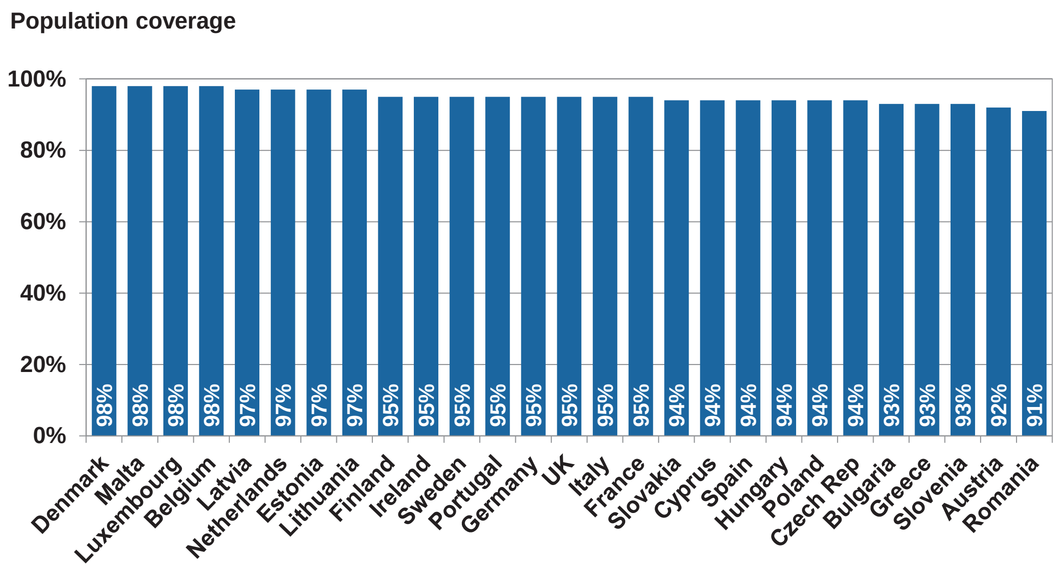
As noted in Section 4.1.3, we anticipate that wireless solutions will be used as (1) the primary means of fast or ultra-fast access in remote, very low density, or hard-to-reach areas; (2) as an imperfect substitute or alternative to wired fast broadband solutions throughout Europe; and (3) wherever mobility or nomadicity[49] is desired.

It is difficult to assess the fraction of the European population that cannot be cost-effectively covered at 30 Mbps with the fixed network. (Since the 100 Mbps target refers only to adoption by 50% of households, we assume that there is no need for mobile to meet this need. The 100 Mbps users can be located in areas that have higher density.)

In Australia, where an ultra-fast government-owned *National Broadband Network (NBN)* is being deployed, 7% of the population is expected to be served by wireless or satellite solutions. The number in Europe might be higher or lower, but this at least provides a starting point for discussion.

The coverage of LTE or LTE Advanced wireless in Europe can be expected to be at least as great as that of 2G and 3G wireless today.[50] This seems to imply that most remote, low density, or hard to reach locations can be served using LTE or LTE Advanced; however, there will predictably be locations that cannot even be served cost-effectively by LTE.

Figure 11: Predicted LTE coverage in 2020



Source: Yardley et al. (2012b).

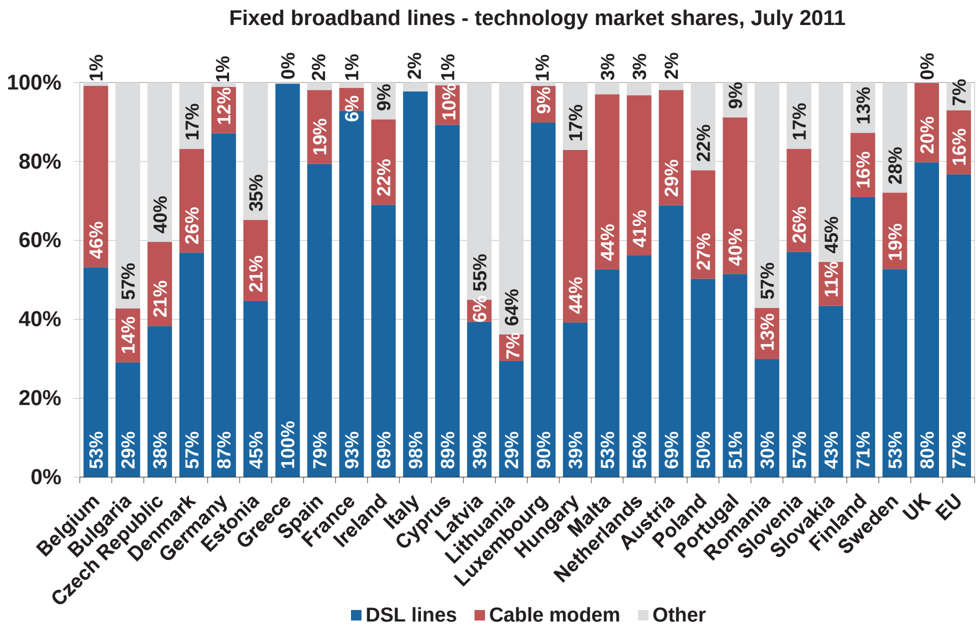
49 *Nomadicity* is the ability to use the service at different locations at different times, but not the ability to use it while in motion.

50 See Yardley, M. et al. (2012b).

4.2.5 Overall adoption of network technologies

Many Member States already have a mix of fixed broadband technologies including telecommunications (copper and in some cases fibre), cable, and sometimes other technologies as well. Note that Figure 12 reflects adoption rather than coverage.

Figure 12: Broadband adoption (lines) by technology and Member State



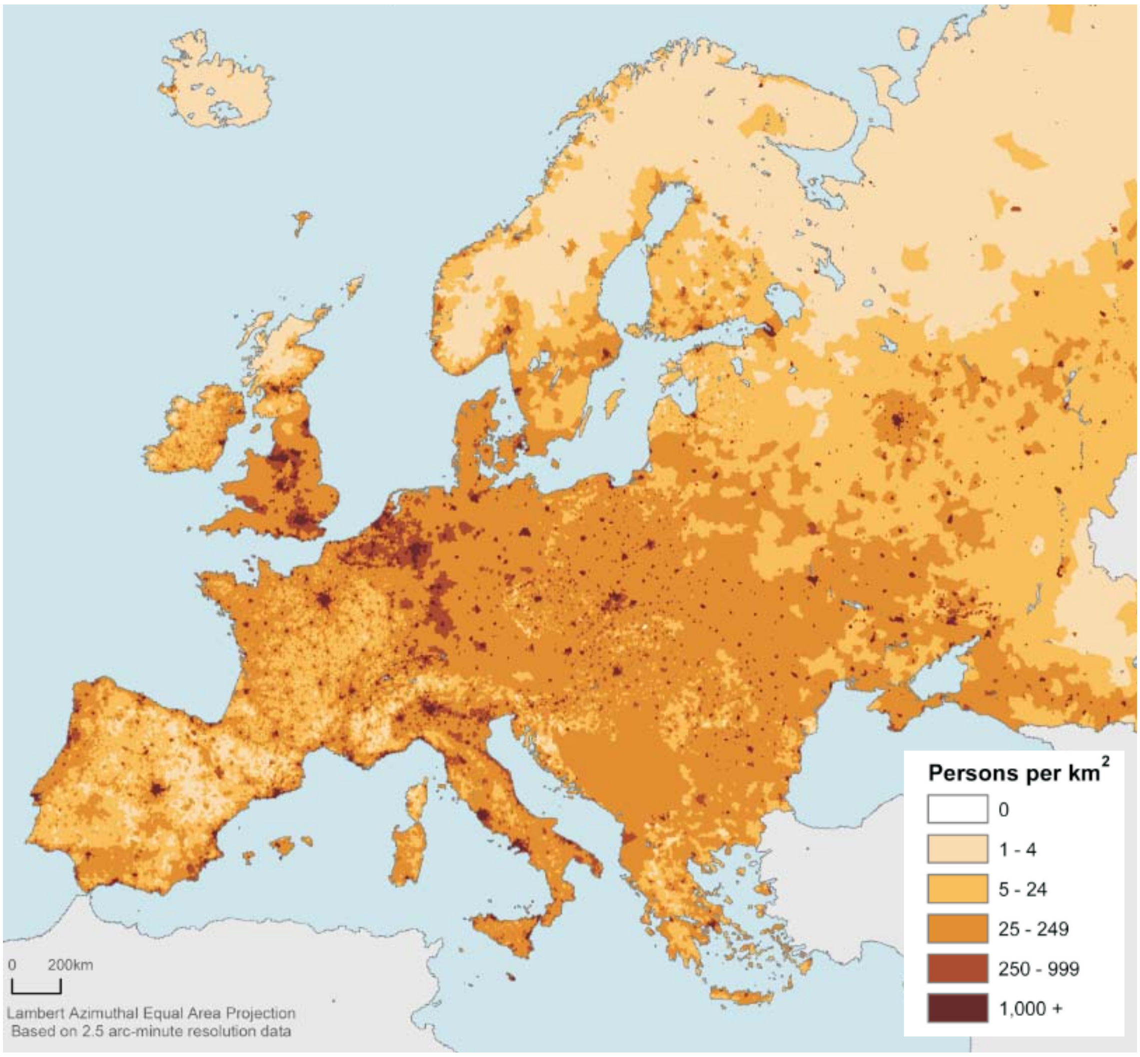
Source: COCOM, Subject: Broadband access in the EU: situation at 1 July 2011.

4.3 Challenges of achieving full coverage

Attempting to meet even the first of DAE objectives (coverage of 100% of Europeans with conventional broadband by 2013) may be more challenging than many have assumed, for a range of reasons.

First, the population density of Europe is highly varied, with fairly dense metropolitan areas (inexpensive per capita to cover) and quite sparsely populated areas, especially in the north.

Figure 13: Population density of Europe



Source: Center for International Earth Science Information Network (CIESIN).[51]

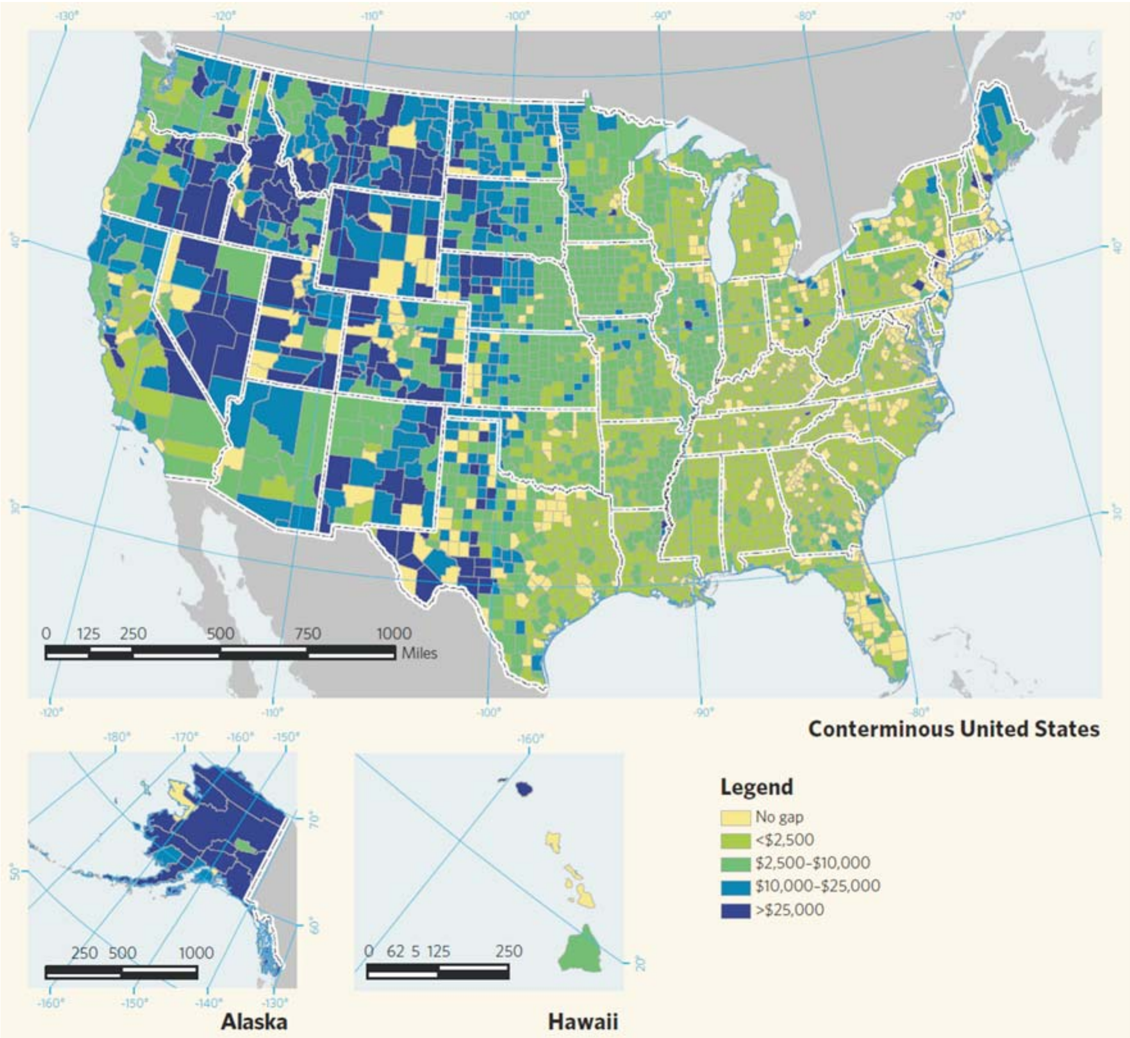
Second, European topography is not particularly helpful to coverage. Many regions in Europe are mountainous.

Third, many regions of Europe historically lacked full coverage of the fixed telephony network. This problem has been ameliorated since the fall of the Iron Curtain, but it may continue to be an issue in some of the Newer Member States (see Section 4.2.1).

51 CIESIN, Population Densitiy of Europe at http://farm6.staticflickr.com/5018/5457012599_e0bd90dd73_b.jpg.

Getting broadband coverage to the most remote areas can be disproportionately expensive. In a comprehensive analysis, the United States quantified the CAPEX and OPEX that would be required to deploy broadband (with 4 Mbps download and 1 Mbps upload speed) to all households in the United States. Underserved areas tend to be mountainous or remote (see Figure 14).

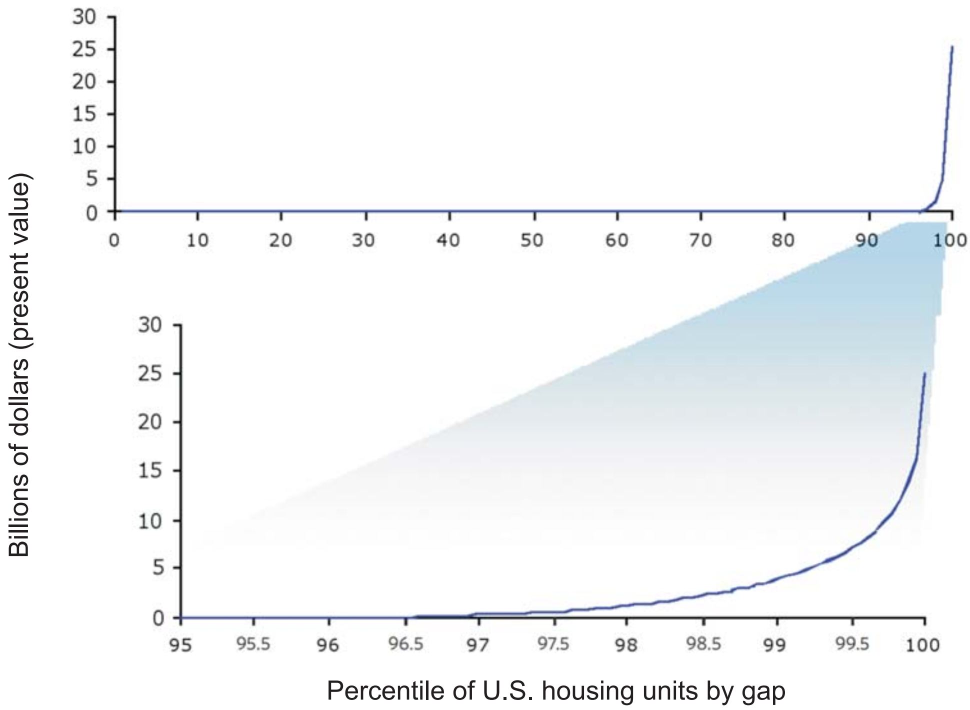
Figure 14: The "broadband gap" in the United States: incremental CAPEX and OPEX needed to achieve 4 Mbps download and 1 Mbps upload speed



Source: FCC: "The Broadband Availability Gap", April 2010.

A striking finding is that a disproportionately large fraction of the "gap" is associated with covering a tiny fraction of the population. The most expensive 250,000 households, representing just 0.2% of all households, represent about half of the gap (see Figure 15).

Figure 15: The broadband deployment “gap” in the United States



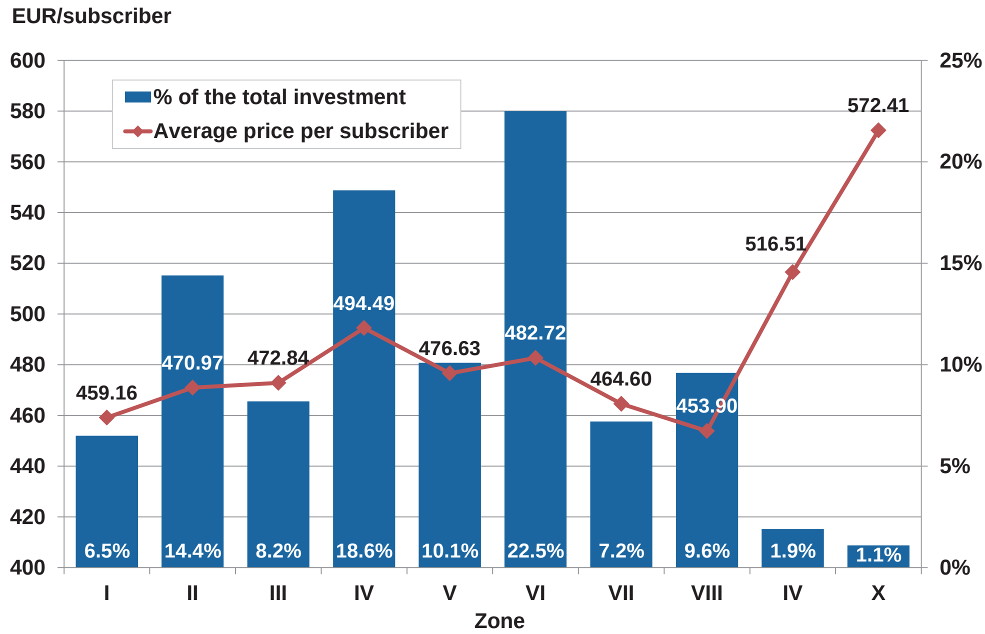
Source: FCC: “The National Broadband Plan”, March 2010.

This may not be as severe a problem in Europe. In Spain, Feijoo and Gomez-Barroso (2010) found that, even though unit costs for covering the lowest density regions in Spain were high, the total cost of coverage in low density areas was modest because so few households were involved (see Figure 16).[52] In analysing the cost of coverage of ten geotypes designated I through X (representing population density from geotype I, with population in excess of 10,000 per Km^2, to geotype X, with population less than 5 inhabitants per Km^2), they found:

“The total expenditure per user remains relatively flat for zones I to VIII but then increases 8,2% and 20% for the most sparsely populated geotypes, IX and X respectively. … Note that the calculations assume coverage for the location of premises, that is, coverage of the population, not for the coverage of the total surface of each geotype. This is the reason why the proportion of the total expenditure is so low in geotypes IX and X in spite of their higher cost per user. In conclusion, the graph shows a pattern of investment relatively close to the distribution of the proportion of the total population among the different geotypes.”

52 See Feijoo, C. and J.-L. Gómez-Barroso (2010b).

Figure 16: Cost of covering different geotypes, from most dense to least dense, in Spain



Source: Feijoo, Gomez-Barroso et al. (2011a).

4.4 Challenges of achieving ultra-fast deployment

It is widely recognised that the costs of full deployment of fibre-based ultra-fast broadband are daunting in light of apparently low incremental Willingness-to-Pay (WTP) on the part of consumers. How great are the challenges?

A recent WIK study[53] attempted to comprehensively quantify the gap between the deployment of fibre-based ultra-fast broadband to 100% of the population of Germany reflecting detailed geographic data on the locations of streets, buildings, and business and residential customers. These particular results were computed for Germany, but they are consistent with previous less detailed results,[54] and similar considerations can be expected to apply in varying degree to all of the Member States.

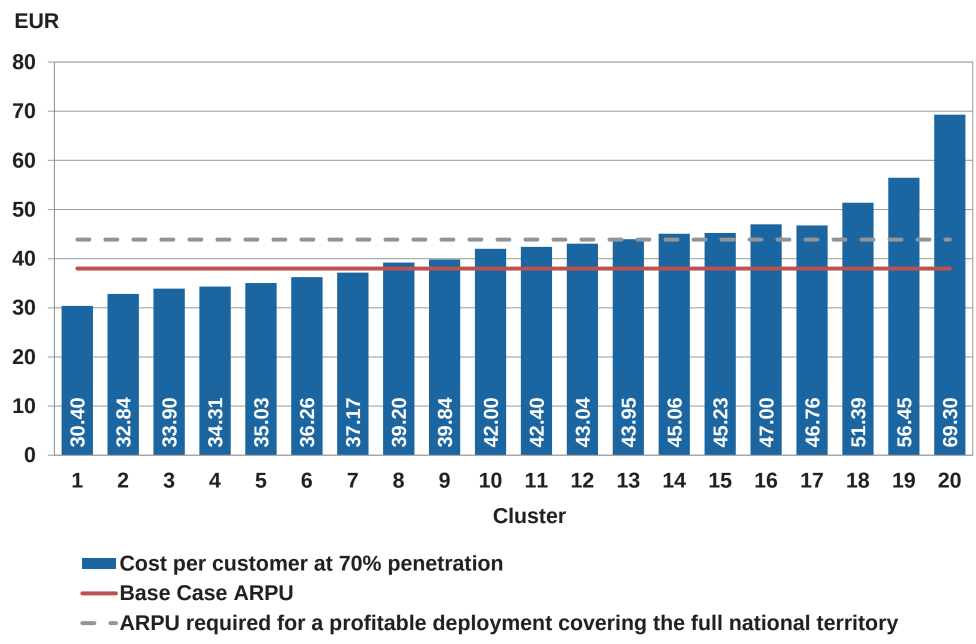
53 See Jay, S., and T. Plückebaum (2011): "Financial requirements for nationwide fibre access coverage", 22nd European Regional ITS Conference, Budapest, 18-21 September 2011; and Jay, S., Neumann, K.-H., and T. Plückebaum (2011): "Implikationen eines flächendeckenden Glasfaserausbaus und sein Subventionsbedarf", WIK Diskussionsbeiträge Nr. 359, Bad Honnef, October.

54 See Elixmann, D., Ilic, D., Neumann, K.-H. and T. Plückebaum (2008): "The Economics of Next Generation Access"; published by ECTA, Brussels, 16 September 2008.

Four fibre-based telecommunications architectures were considered: PMP GPON, P2P Ethernet, P2P GPON, and FTTB P2P DSL.[55] Neither cable television infrastructure nor wireless was considered. The national territory was then segmented into twenty different areas (geotypes) based on population density.

A key driver is the *Average Revenue per User (ARPU)*. An ARPU of € 38 for ultra-fast broadband was felt to be achievable; however, for a profitable deployment of FTTH P2P Ethernet covering the full national territory, an average ARPU of € 44 would be required (see Figure 17). In geotypes 1 through 7, where population density is greatest and where the unit cost of deployment is consequently the lowest, fibre-based ultra-fast broadband could reasonably be expected to deploy based solely on market-based decisions of market players. For the less dense geotypes, ultra-fast broadband would cost more than the expected € 38 ARPU, and would therefore be unlikely to deploy without some form of public policy intervention.

Figure 17: Cost and ARPU per customer per month for FTTH P2P Ethernet at 70% penetration



Source: WIK.[56]

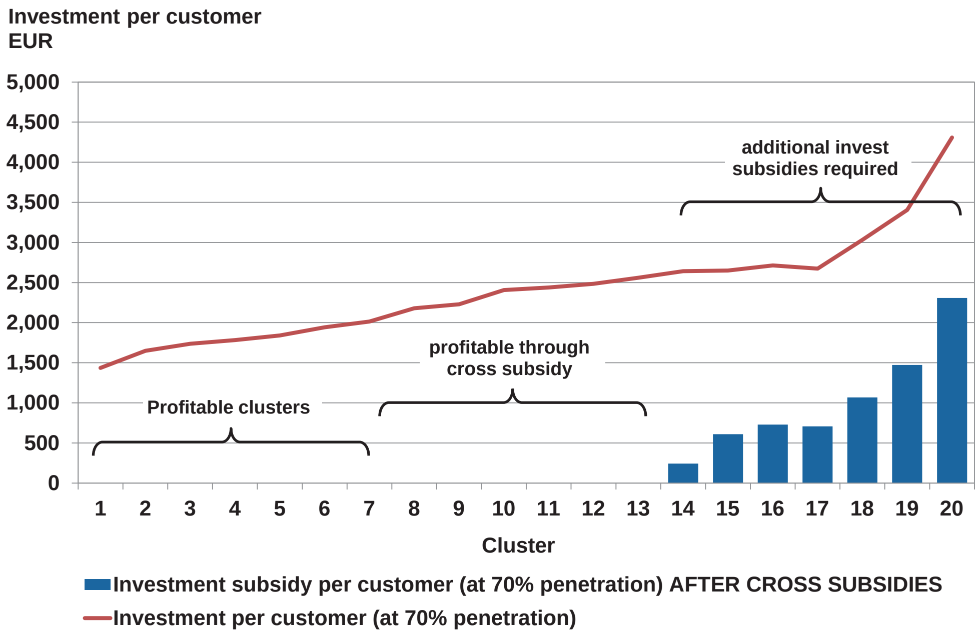
55 These terms respectively signify: (1) PMP GPON is Point-to-Multipoint GPON architecture with splitters in the access network, close to the customer premises, (2) P2P Ethernet is Point-to-Point fibre access network with single fibres per home and Ethernet switches concentrating the customer traffic at the central MPoP (ODF) sites. (3) P2P GPON is Point-to-Point fibre access network as before, but GPON splitters and OLT at the central MPoP sites, and (4) FTTB P2P DSL is Point-to-Point fibre access network with single fibre per building and traffic concentrating DSLAMs in the basement of the buildings.

56 See Jay, S., and T. Plückebaum (2011); Jay, S., Neumann, K.-H. and T. Plückebaum (2011).

One purely market-based solution would be to depart from geographic averaging of prices. If customers paid for their fibre-based ultra-fast access based on the individualised cost of deploying it, it could be expected to deploy to the entire national territory. This would imply end-user prices corresponding to an ARPU of just over € 30 in the densest parts of Germany, but an ARPU of € 70 in the least dense regions.

If a market player sought to maximise coverage without losing money, rather to maximise profits, it would be possible to cover far more of the population. In effect, those in geotypes of higher density would subsidise those in geotypes of lower density. This would require some form of public policy intervention, since a market player would not choose to do this, but it does not depend on subsidies. Under these circumstances, geotypes 1 through 13 could be deployed. The remaining low density geotypes would still remain without fibre-based ultra-fast broadband coverage in the absence of the application of additional public policy measures (for example, subsidies of one form or another).

Figure 18. Investment subsidies required per customer for each geographic cluster



Source: WIK.[57]

57 See Jay, S., and T. Plückebaum (2011); Jay, S., Neumann, K.-H. and T. Plückebaum (2011).

The apparent conclusions are that a full 100% fibre-based ultra-fast broadband coverage cannot be profitable in Germany under today‘s circumstances. FTTH would be profitable for 25-45% of German lines with no public policy intervention whatsoever. Cross-subsidy from areas of higher density to those of lesser density would expand coverage, but not enough to achieve 100% coverage. Either ARPU would have to increase some € 6 per month (from € 38 to € 44 per month), or else an investment subsidy of up to €2,500 per access would appear to be required.[58]

It is worth noting that these results are very sensitive to profit, which is the *difference* between price and cost. A small change in either price or cost would produce a large change in the conclusions. The costs are fairly well understood at this point. The evolution over time of price (ARPU) is much less certain.

The results are also very sensitive to the customer penetration (the fraction of homes passed that are connected). The study assumes a penetration of 70%, which in turn depends on availability of the fibre-based access as an open access wholesale product; otherwise, it is unlikely that the investor could achieve a 70% penetration on its own. The remaining 30% of each cluster is assumed to be served (if at all) by mobile or cable.

This analysis (which is based solely on copper and fibre-based telecommunications, and does not otherwise reflect cable or mobile) has many implications that are probably relevant not only to Germany, but to most of the Member States. Full achievement of the three DAE objectives based solely on fibre-based telecommunication technologies without intervention or subsidy is unlikely in many Member States. Factoring cable broadband and wireless broadband into the analysis can help significantly to close this gap (as we shall demonstrate in Chapter 6); however, the effects will vary among the Member States, in part as a function of the degree of coverage of the cable television network.

58 The WIK study considers many other potential interventions as well, each with its own advantages and disadvantages.

5 TECHNOLOGICAL FEATURES OF A CABLE BROADBAND NETWORK

Key Findings

Key Findings

- Our focus in this study is on systems that are based on *Hybrid Fibre Coaxial (HFC)* cable, thus using coaxial cable at least at the point of access by the customer. At the same time, it is important to note that the evolution of cable systems is intertwined with that of the telephony network, and that the evolution of both (and, for that matter, also the evolution of the mobile network) is to a significant degree fibre-based.

- Cable systems today have evolved into *Hybrid Fibre Coaxial (HFC)* networks that combine many of the best characteristics of coaxial cable systems with those of a high capacity fibre optic-based distribution system.

- The upgrade to HFC cable systems to enable state-of-the-art bandwidth is comprised of two distinct processes: (1) upgrade to EuroDOCSIS 3.0 standards, and (2) driving fibre progressively close to the end-user as and when needed to meet customer demand. Both upgrades have been in progress for some time.

- The cost of upgrading existing digital cable systems to EuroDOCSIS 3.0 is minimal.

- The cost of driving fibre into the network can be significant; however, the upgrade can be undertaken as and when needed. This cost can vary greatly depending on how the existing cable plant was deployed, the availability of existing ducts, and also as a function of labour costs that vary among the Member States. In any event, upgrading existing digital cable is substantially less expensive than deploying new fibre-based telecommunications networks, thanks to the benefits of sharing existing coaxial cable to multiple customer premises. Some of these costs have already been incurred.

- There is no imbalance between the cost of incrementally upgrading cable systems in comparison with customer willingness to pay for the upgrades; consequently, there is no need for subsidy.

- Many capacity enhancements improve both upstream and downstream capacity. A more comprehensive approach to bringing upstream capacity in line with downstream would depend on a reallocation of the cable frequency plan, moving the *diplex split* to a value higher than the current 65/85 MHz. This is entirely possible, and has been under study for some time. The industry has seen no urgency in putting such a solution in place because there has been little customer demand for upstream data bandwidth. The biggest single impediment is that such a shift would conflict with analogue FM radio (which enjoys significant use in some markets) at 88 to 108 MHz.

This chapter assesses the technical capabilities of cable, and the prospects for long term evolution of those capabilities.

Our focus in this study is on systems that are based on *Hybrid Fibre Coaxial (HFC)* cable, thus using coaxial cable at least at the point of access by the customer. The evolution of cable systems is intertwined with that of the telephony network, and that the evolution of both (and, for that matter, also the evolution of the mobile network) is to a significant degree fibre-based.

- Modern cable systems are based on *Hybrid Fibre Coaxial (HFC)* cable, where fibre is used to distribute signals to and from coaxial *drop cable segments*.
- Upgrade to HFC cable systems is comprised of two distinct processes: (1) upgrade to EuroDOCSIS 3.0 standards, and (2) driving fibre progressively close to the end-user as and when needed to meet customer demand. Both upgrades have been in progress for some time.
- Some cable operators choose to use purely fibre-based systems (e.g. GPON) for some customers, for example in greenfield development settings.

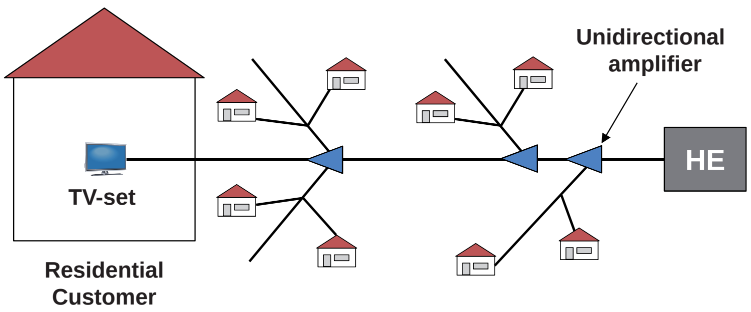
The upgrades that we are considering in this chapter are primarily concerned with capacity, but there is also an issue regarding specifically upstream capability. It is an open question as to how much is needed. The Cisco VNI report (2011) notes that Internet traffic demand, contrary to what many have assumed, is becoming more asymmetric over time, not less. “With video growth, Internet traffic is evolving from a relatively steady stream of traffic (characteristic of P2P) to a more dynamic traffic pattern. … With the exception of short-form video and video calling, most forms of Internet video do not have a large upstream component. As a result, traffic is not becoming more symmetric as many expected when user-generated content first became popular. The emergence of subscribers as content producers is an extremely important social, economic, and cultural phenomenon, but subscribers still consume far more video than they produce. Upstream traffic has been flat as a percentage for several years …”

Many capacity enhancements improve both upstream and downstream capacity. A more comprehensive approach to bringing upstream capacity in line with downstream would depend on a reallocation of the cable frequency plan (see Section 5.3.4). This is entirely possible, and has been under study for some time. The industry has seen no urgency in putting such a solution in place because there has been little customer demand for upstream bandwidth.

5.1 Architecture and topology

The traditional cable TV network was optimised to deliver one-way analogue broadcast TV services to cable network subscribers. As the following figure shows, the key elements of a traditional cable network are (1) headends, which house facilities and equipment (e.g. terrestrial and satellite antennas) for receiving TV signals, and for the conversion of signals into a suitable format which then are distributed over the cable network;[59] (2) the copper coaxial physical infrastructure; and (3) the unidirectional amplifiers (to compensate for attenuation on the coaxial cable).

Figure 19:The traditional one-way cable TV network

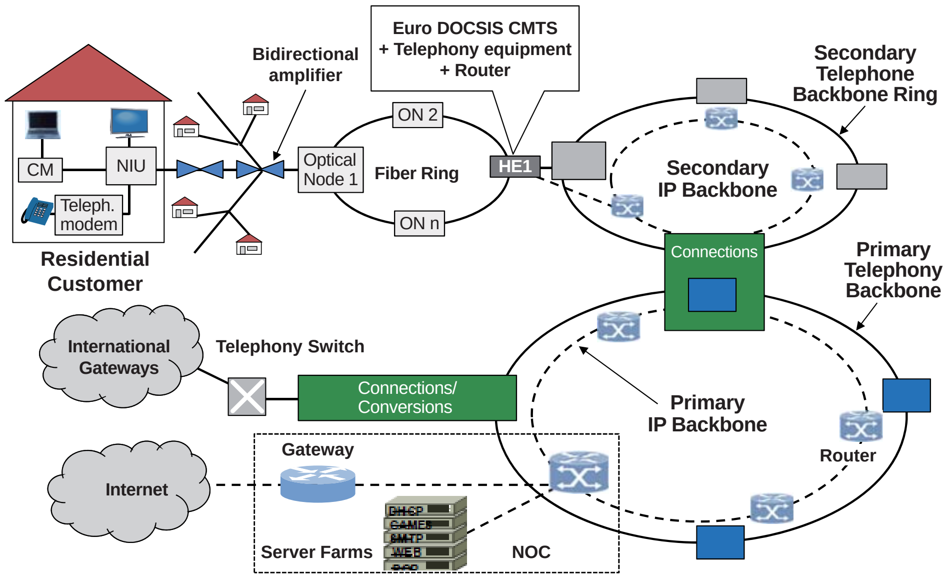


Source: Cable Europe Labs (2009): Cable network handbook; CEL-TR-HFC-V4_3-091001.

The architecture and topology of a modern cable network that is able to offer triple play services is different in fundamental ways. Figure 20 gives an overview of the main characteristics of a HFC/DOCSIS cable infrastructure.

59 A headend was able to serve more than a million households.

Figure 20: Characteristics of a HFC/DOCSIS cable infrastructure



Source: Cable Europe Labs (2009): Cable network handbook; CEL-TR-HFC-V4_3-091001;
CM: Cable Modem; NIU: Network Interface Unit; ON: Optical Node; CMTS: Cable Modem Termination System; HE: HeadEnd; NOC: Network Operation Center.

Figure 20 shows that a typical broadband cable network comprises network operation facilities; facilities for the provision of television, IP and telephony services; and supra-regional, regional and local physical infrastructures. In more detail, the essential elements of a cable network are the following:

- **Master headend (and the network operation centre (NOC)):** These elements are responsible for the reception of television channels (usually via fibre or satellite). Moreover, there are gateways to the PSTN (telephony equipment), gateways to the Internet (IP routers), and servers for providing a range of services.[60] Where there are multiple headends, they are typically linked via supra-regional backbones based on fibre optics.

- **Regional headends (also called "area hubs"):** These headends are data centres requiring a power supply, and security arrangements. They are typically connected via a fibre transport ring (regional backbone). Regional headends are responsible for the conversion of television signals into HF signals (compatible with cable networks) and for the coupling with IP signals. Each regional headend contains optical transmitters and receivers, and can serve as the home of a

60 Examples are DHCP (Dynamic Host Configuration Protocol), games, web, e-mail (SMTP, Simple Mail Transfer Protocol) and Point of Presence (traffic exchange with third parties).

CMTS (Cable Modem Termination System). The CMTS is the intelligence of a broadband cable system. Key functions include (1) addressing the receiving party of an individual message, and (2) administering transmission rights in order to prevent collisions on the shared medium.

- **Fibre nodes:** From each regional headend, a network of optical nodes (fibre hubs) departs which usually are typically connected via a fibre ring. The fibre node is the interface between optical and electrical signalling, i.e. power supply is necessary. Each fibre node connects a specific "cluster" of end user homes.
- **The drop cable segment:** This segment covers the network part between a fibre node and the end user households. It consists of coaxial copper infrastructure (usually buried in the ground) branching out via splitters/taps).[61] The copper infrastructure requires installation of (bi-directional) amplifiers in order to provide sufficient signal strength at the end user's premise.[62]

5.2 Performance of EuroDOCSIS 3.0

EuroDOCSIS 3.0 together with the DVB-C standard for digital cable represents the current state of the art for Europe as regards delivery of data, voice, and video over a cable television system.[63] It is the cable technology platform that competes most directly with fibre-based NGA, and is therefore a central consideration in the analysis in this report. A substantial fraction of all cable in Europe has been upgraded to EuroDOCSIS 3.0, but not all (see Section 4.2.3). Most European non-DOCSIS 3.0 cable is presently implemented as EuroDOCSIS 2.0.

The cost of upgrading a DOCSIS 2.0 cable system to DOCSIS 3.0 is fairly small. There are no major impediments to the upgrade. Within the 2020 time frame that is relevant for DAE objectives, we expect that substantially all European cable will have been upgraded to EuroDOCSIS 3.0 (if not to a successor).

The migration from DOCSIS 2.0 to DOCSIS 3.0 technologies marks a major leap forward in the performance of a cable network.

A EuroDOCSIS 2.0 system can deliver raw downstream bit rates of from 38 Mbps (64-QAM) to 51 Mbps (256-QAM) in an 8 MHz channel, and raw upstream bit rates of about 30 Mbps (64-QAM) in a 6.4 MHz channel.[64]

61 Splitters are bi-directional passive components used to split and combine signals over different paths (working in a symmetrical way, i.e. equal distribution of the signal energy to all connectors). Taps, are providing basically the same function as a splitter, however, they work in an asymmetrical way, i.e. one output port is the main output.

62 The amplifiers compensate for attenuation.

63 EuroDOCSIS 3.0 is routinely used with DVB-C modulation. This may evolve over time into DVB-C2.

64 QAM stands for Quadrature Amplitude Modulation.

In comparison to DOCSIS 2.0, DOCSIS 3.0 enables bonding of four or more physical DOCSIS 2.0 channels to achieve higher bandwidth logical channels.[65] Current EuroDOCSIS 3.0 technology (based on 8 MHz channels, rather than the 6 MHz channels that are used in DOCSIS in North America) is able to deliver much higher bandwidth than prior versions of DOCSIS. Usable throughput is roughly:

- Downstream: more than 200 Mbps through the bonding of four channels, or more than 400 Mbps through the bonding of eight channels; and
- Upstream: more than 100 Mbps through the bonding of four channels.

Technical progress as to DOCSIS capabilities is, however, very dynamic. It is therefore to be expected that substantially higher raw bit rates will be available downstream and upstream in the future. Indeed, the equipment available today allows already bonding of 8 channels. This yields 400 Mbps of usable throughput downstream. Development of CPE capable of 16 channels downstream and 8 channels upstream is already under way. The expectation in the medium and longer term (5-10 years) is that 32 channels downstream could be available. Indeed, Virgin Media has announced plans to offer 1.5 Gbps service to selected customers on a trial basis,[66] and other cable operators have demonstrated still higher ultra-fast speeds over cable.[67]

5.3 Upgrading a cable network

Due to the inherent characteristics of an HFC cable network, whatever data capacity is available is shared by all connected customers. With proper management, however, the data capacity can meet realistic customer requirements under quite a wide range of assumptions. First, one must bear in mind that the capacity required to support linear video is separate from the capacity used to support data (as is also the case with GPON). Second, the cable network operator can progressively upgrade the network infrastructure, *as needed and on an incremental basis*, to serve progressively fewer subscribers per cable segment, thus increasing the effective bandwidth available per subscriber.

In this section, we deal specifically with overall capacity upgradability within the existing frequency plan.

65 Moreover, DOCSIS 3.0 supports Internet Protocol Version 6 (IPv6).

66 “Virgin Media ups broadband pace to 1.5Gbps”, Seek Broadband, 20 April 2011, http://seekbroadband.com/focus/2011/04/20/ispwatch/virgin-media-ups-broadband-pace-to-1-5gbps/.

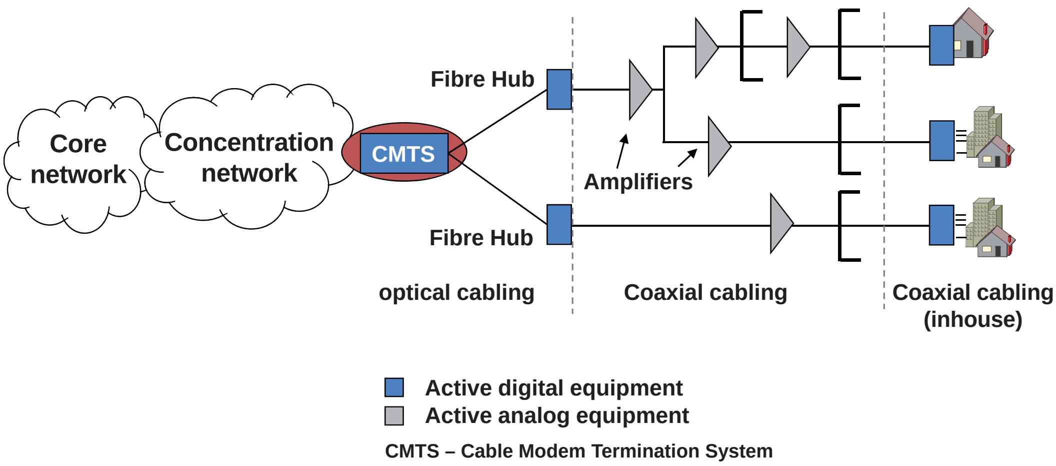
67 Kabel Deutschland (KDG) recently showed in a field test that an 862 MHz upgraded cable network is able to broadcast download speeds of up to 4.7 Gbps. See KDG Press Release May 31, 2012; http://www.kabeldeutschland.com/en/presse/pressemitteilung/unternehmensnachrichten/may-31-2012.html and http://www.digitalfernsehen.de/index.php?id=87325. In order to implement such a solution in practice, it is necessary to bond a very high number of channels which, in turn, would require the freeing up of frequencies from traditional TV use (see Section 5.3.4).

One can distinguish among three stages regarding the migration from a traditional broadcasting infrastructure to a fully Internet-capable state-of-the-art EuroDOCSIS 3.0 cable network, the first of which has long since been substantially completed throughout Europe:

- Upgrade of the traditional analogue broadcast cable network to enable digital broadband communications,
- Upgrade to a EuroDOCSIS 3.0 enabled network,
- Upgrade of the EuroDOCSIS 3.0 enabled network by progressively driving fibre deeper into the network if and as needed in order to meet capacity requirements. This process is already ongoing; thus, a portion of these costs have already been incurred.

In understanding the cost and complexity of these upgrades, it is helpful to consider the physical and logical structure of the HFC/DOCSIS cable infrastructure, as depicted in Figure 21. Changes to the CMTS tend to be very inexpensive on a per-subscriber basis, because a single CMTS is shared over a great many subscribers. Changes that require the driving of fibre deeper into the network have more complex implications, and are associated with costs that could vary greatly depending on the degree to which the potential future need for additional fibre was already foreseen at the time that the cable network was initially deployed. Cable networks deployed across the European Member States differ considerably in this regard.

Figure 21: Main characteristics of a HFC/DOCSIS cable infrastructure



Source: WIK-Consult.

5.3.1 Upgrade of traditional broadcast cable networks to enable broadband communications

Considerable work is needed to enable a traditional cable network to deliver broadband connectivity; however, this has long since been accomplished throughout Europe.

5.3.2 Upgrade from a DOCSIS 2.0 to a DOCSIS 3.0 enabled network

The migration from DOCSIS 2 to DOCSIS 3.0 requires:

- Implementation of DOCSIS 3.0 modules into the CMTS (an upgrade that is typically carried out for the entire CMTS);
- Possibly replacement of a module within the fibre hubs;
- Replacement of the DOCSIS 2.0 modem at the customer‘s premises for those customers who require (and pay for) the higher bandwidths that are only possible with DOCSIS 3.0.[68]

5.3.3 Upgrade of a DOCSIS 3 enabled network

Cable is a shared medium; nonetheless, cable operators have considerable control over the bandwidth available per user.

In an HFC/DOCSIS cable network, resources are shared among end-users in the fibre cluster. As with any shared medium, competition for resources with other users can introduce delay, affecting the performance seen by the user.

It is important to bear in mind that *all* modern data networks are shared in some degree. Networks differ in where the sharing takes place. Cable networks enjoy significantly lower unit costs than pure fibre-based networks thanks to shared coaxial cable; however, they also require more careful capacity management due to this same sharing.

Cable operators are able to increase capacity in a number of ways in order to meet the needs of their customers.

- First, a cable operator might enlarge the frequency spectrum used on its network. This option is relevant for an operator that currently does not make use of the entire frequency spectrum up to 862 MHz.[69]
- Second, the cable operator might reduce the number of competing end-customers served per fibre hub and thus increase the available bandwidth provided in a given cluster by segmenting the latter into two (or more) clusters (HFC segmentation/ node splitting).

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68 DOCSIS 3.0 and DOCSIS 2.0 modems are interoperable; thus, a cable network can be upgraded over time with both types of modems in the field. Those who have DOCSIS 2.0 modems are limited to DOCSIS 2.0 speeds.

69 An enlargement beyond this threshold is possible. Amplifier technology today can handle up to 1 GHz. Theoretically, an enlargement beyond 1 GHz is possible. However, increasing challenges are foreseeable due to both physics (attenuation) and economic (costs of additional investments) considerations.

The latter option can be implemented in various ways. More CMTS can be deployed to serve a group of users. More fibre nodes can be deployed to a street cabinet. Depending on specific circumstances, such upgrades might or might not require physical deployment of additional fibre.

HFC segmentation/node splitting is inexpensive to implement in cases which do not require carrying out civil works (digging, burying new fibre), for example in cases where surplus fibre is available. A number of Liberty Global networks, for example, are constructed using fibre rings that contain redundant fibre. Unit costs of upgrading these networks can be very low.

The upgrade will tend to be more expensive in those cases where civil works are required; however, the cable network will still tend to enjoy unit cost advantages in comparison with pure fibre-based NGA networks. First, as long as multiple customers share the same existing coaxial cable, unit costs will tend to be lower than Fibre-to-the-Home (FTTH) solutions where copper to every customer must be replaced with fibre. Second, upgrades can be undertaken gradually and incrementally, if and as needed.

Cable systems can thus be incrementally upgraded, to 2020 and well beyond, in order to meet any consumer demand that can reasonably be expected.[70]

5.3.4 Changing frequency allocations within a cable system

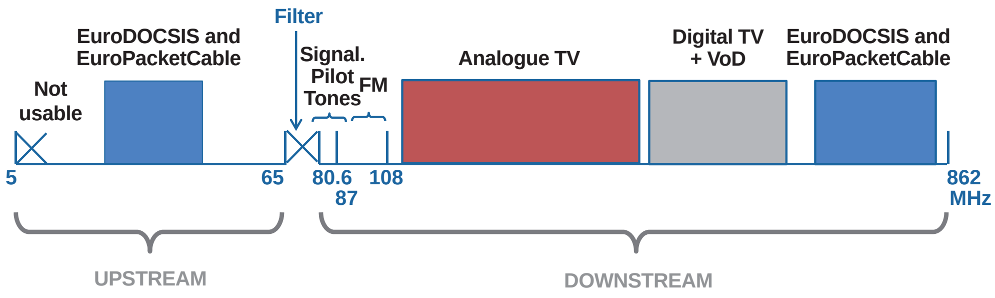
Cable systems offer limited bandwidth upstream. This reflects, of course, the historical reality that cable systems were designed for their initial, primary mission of delivering linear video to consumers. Because reverse capacity was only later added to cable architecture, it is constrained.

Many have assumed that limited upstream bandwidth is an immutable law of nature. In reality, cable systems are able to adapt as customer needs change. The limited bandwidth available upstream is not an inherent, hard and fast restriction in cable technology. The cable frequency plan could be rearranged if there were a commercial need to do so; however, doing so would be at the expense of sacrificing bandwidth for existing linear video or audio applications. To date, there has not been sufficient customer demand to warrant such a change – the available upstream bandwidth has been sufficient to meet customer needs, in general.

The frequency spectrum that currently is available in cable networks covers the range of 5 MHz up to 862 MHz. The following figure gives an overview of the usual allocation of these frequencies to the different service segments provided over a cable infrastructure.

70 Section 2.3 shows that individual bandwidth demand (and willingness to pay) in all likelihood will remain well below the 100 Mbps access speed threshold addressed in the DAE, even though a migration from today's traffic patterns towards more bandwidth hungry video based services and applications can be expected. Thus, cable systems (and also wireless systems) that share bandwidth among multiple users will continue to be relevant well into the future.

Figure 22: Allocation of downstream and upstream spectrum within cable networks



Source: Cable Europe Labs (2009): Cable network handbook; CEL-TR-HFC-V4_3-091001.

Figure 22 makes clear that the frequency spectrum allocated to upstream services (from 5 to 65 MHz) is usually much smaller than the spectrum allocated to downstream services (from 80 to 862 MHz). The available downstream frequency spectrum is allocated to the following services:

- FM radio services,
- analogue TV channels,
- digital TV channels and VoD services,
- Euro DOCSIS (and Euro Packet Cable) services.

A major revision to the frequency allocation plan would entail significant disruption, but it has been under discussion for some time, and could be implemented if there were sufficient consumer demand. A number of technical, economic and practical considerations come into play.

First, cable operators would be reluctant to lose video channels that they offer today. Fortunately, cable benefits from the same improvements that enabled broadcast spectrum to be reassigned under the Digital Dividend. The efficiency of video transmission improved greatly with the move from analogue to digital. Analogue TV channels in Europe require a frequency range of 8 MHz per channel. With digital transmission, cable television can now carry hundreds of channels, in comparison with analogue-only cable systems that carried only a bit over thirty channels. Indeed, in the digital world, operators typically support 30 to 35 analogue services, hundreds of standard definition TV services, and tens of high definition services.

As a second and related point, it would be feasible to increase the available spectrum not only above 862 MHz, not only to 1 GHz (1,000 MHz),[71] but potentially still higher, thus increasing the spectrum available for broadcast to compensate for shifting spectrum from downstream to upstream use. One can reasonably expect that this would require replacing amplifiers in the cable network,[72] and that the new frequencies would not necessarily be visible to existing customer premises equipment (e.g. television sets).

A change in the frequency plan such that the *diplex split* – the dividing line between upstream and downstream capacity – came at a point higher than the current 65/85 MHz would in most respects be simple. *Diplex filters* in fibre nodes and amplifiers would need to be replaced. If the diplex filters are pluggable units, as is often the case, a change in the diplex split would not in and of itself require replacement of fibre nodes or amplifiers.[73]

Television sets routinely scan from at least 85 MHz to 860 MHz to identify the available spectrum. Within the spectrum that they are designed to use, there should in principle be no difficulty in automatically accommodating a different frequency plan (i.e. with a lower bound somewhat higher than 85 MHz).

Cable modems already in use at the customer premises would presumably continue to operate using the familiar spectrum allocations on the cable. They would not be able to use the new allocations, but could continue to operate as they have always operated. This is similar to the way in which the upgrade from DOCSIS 2.0 to DOCSIS 3.0 has been handled.

One nasty problem would remain. Increasing the diplex split significantly above 65/85 MHz would result in an overlap with analogue FM radio, which is used to a substantial degree in for example Germany, Belgium and the Netherlands.

71 A Cable Labs working group called *AMP (Advanced Mac and PHy)* is working on this.

72 This might pose special challenges in Germany due to the historical separation between Level 3 and Level 4 cable operators.

73 As previously noted, the amplifiers might be replaced at the same time anyway in order to increase the total amount of spectrum available.

6 COSTS OF MEETING DAE GOALS

Key Findings

- Studies of incremental deployment costs of ultra-fast broadband in Spain by Feijoo and Barroso found that population density plays a huge role. LTE was more expensive than fixed solutions where population density exceeded 3,000 inhabitants per square kilometre (Km2). Conversely, upgrades to VDSL or to FTTH became more expensive on a per-subscriber basis as the population density declines. Cable costs (for areas where digital cable, but not necessarily EuroDOCSIS 3.0, is already deployed) are, by contrast, largely independent of density.

- The recently published study by J. Hätönen of the European Investment Bank (EIB), represents one of the few studies of the costs of achieving DAE goals that explicitly considers technologies other than FTTx. They address ambiguities in the definition of the DAE goals by means of four scenarios, two of which (Basic and Advanced) are realistic in our view. Under these scenarios, the use of cable potentially reduces cost of meeting DAE objectives by up to 30%, with results (in terms of savings per household) that differ greatly among the Member States (largely as a function of the degree to which cable is deployed).

- Whether policymakers would prefer to take that "Cable Dividend" as a cost savings, rather than a gain in facilities-based competition, is a separate question.

- The Feijoo/Barroso and EIB studies seem to be in reasonably good agreement for Spain, where they overlap.

Key Findings

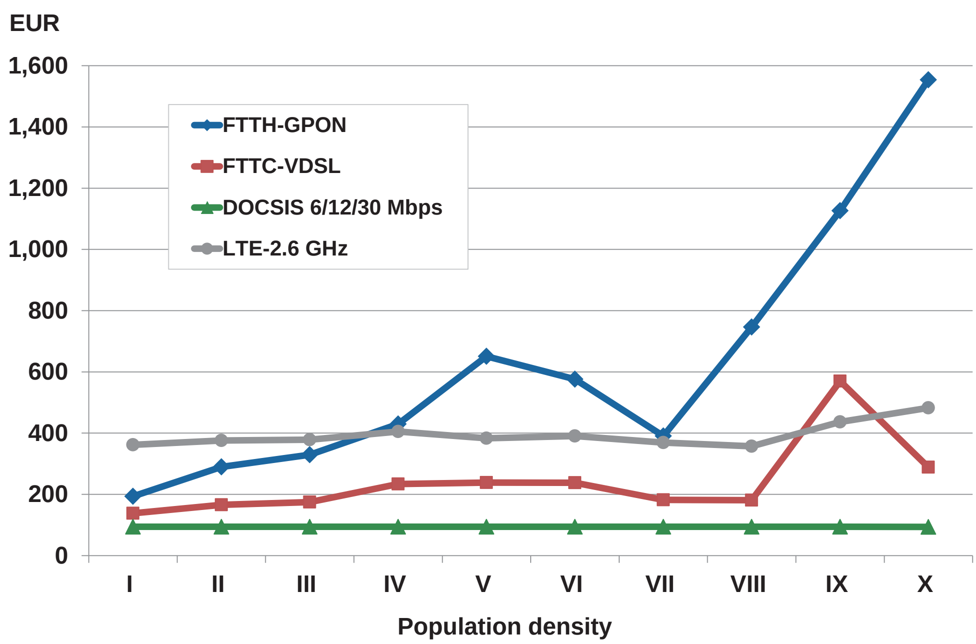
In this chapter, we consider the relative costs using different technologies, and various overall cost projections from the literature.

6.1 Relative deployment costs using various technologies

In a series of insightful studies, Feijoo, Gomez-Barroso et al. considered the cost implications of a least cost deployment of ultra-fast Next Generation Access (NGA) in Spain.[74] Their cost estimates distinguish among ten categories of geographic areas (*geotypes*) with distinct levels of population density, ranging from less than 5 inhabitants per square kilometre to more than 10,000 inhabitants per square kilometre. They assessed the capital expense[75] associated with deploying basic service using Fibre-to-the-Home (FTTH) / GPON, using Fibre-to-the-Curb / VDSL, using DOCSIS 3.0 cable at speeds of 6, 12 or 30 Mbps, and using wireless (LTE at 2.6 GHz).

Population density plays a huge role in these costs. They found that LTE was more expensive than fixed solutions where population density exceeded 3,000 inhabitants per square kilometre (Km^2). Conversely, upgrades to VDSL or to FTTH became more expensive on a per-subscriber basis as the population density declines. Cable costs (for areas where digital cable, but not necessarily EuroDOCSIS 3.0, is already deployed) are, by contrast, largely independent of density.

Figure 23: Annualized cost (Present Value) of CAPEX per user (€)



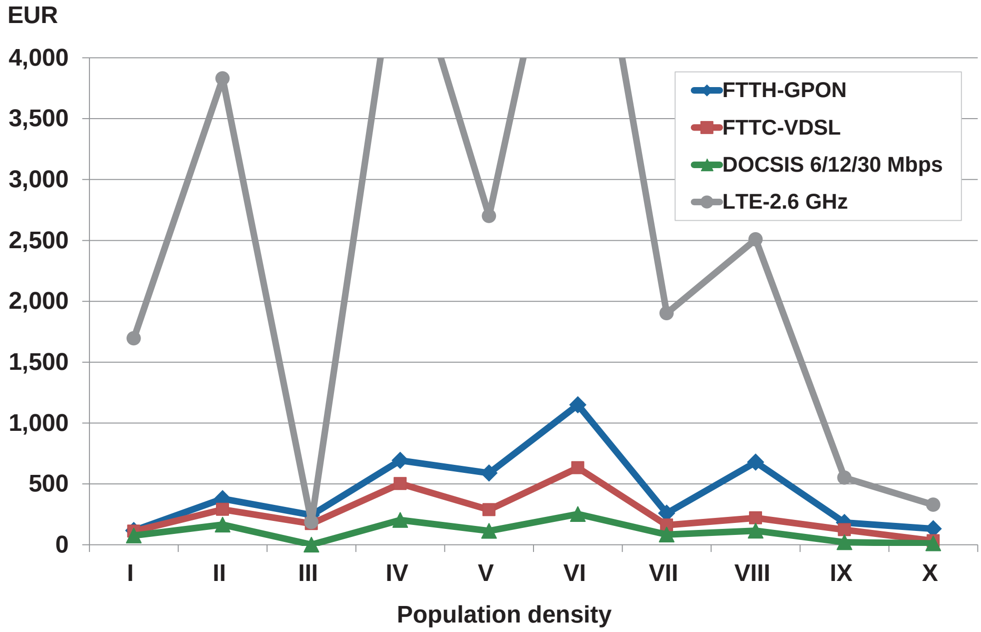
Source: Feijoo / Gomez-Barroso (2010a).

74 See Feijóo, C. and J.-L. Gómez-Barroso (2010a); Feijóo, C., Gómez-Barroso, J.-L., Ramos, S. and R. Coomonte (2011b); and Feijóo, C., Gómez-Barroso, J.-L., Ramos, S. and R. Coomonte (2011a) op. cit.

75 CAPEX expressed in terms of annualised Present Value (PV) in Euro.

If, however, one assumes that there is a requirement for guaranteed bandwidth of 10 Mbps, then the fixed solutions are greatly superior to wireless. LTE costs are highly sensitive to overall bandwidth requirements, and thus even more sensitive than fixed network costs to the number and density of users in type of geographic area (geotype).

Figure 24: Annualized cost (Present Value) of CAPEX per user (€) with a requirement for a guaranteed 10 Mbps



Source: Feijoo / Gomez-Barroso (2010a).

It is worth noting once again that Cisco VNI data strongly suggest that average data consumption per household during the busy hour will be less than 2 Mbps, even in 2020. We are thus much closer to the situation of Figure 23 than that of Figure 24 for the foreseeable future.

6.2 Overall incremental deployment costs

The recently published study by J. Hätönen of the European Investment Bank (EIB),[76] based in part on earlier non-public work by Pantelis Koutroumpis, represents one of the few studies of the costs of achieving DAE goals that explicitly considers technologies other than FTTx. The analysis appears to be thoughtful and well done.

The EIB study considered the ambiguities in the DAE objectives, and addressed them by analysing deployment costs in four different scenarios, each with its own interpretation of bandwidth.

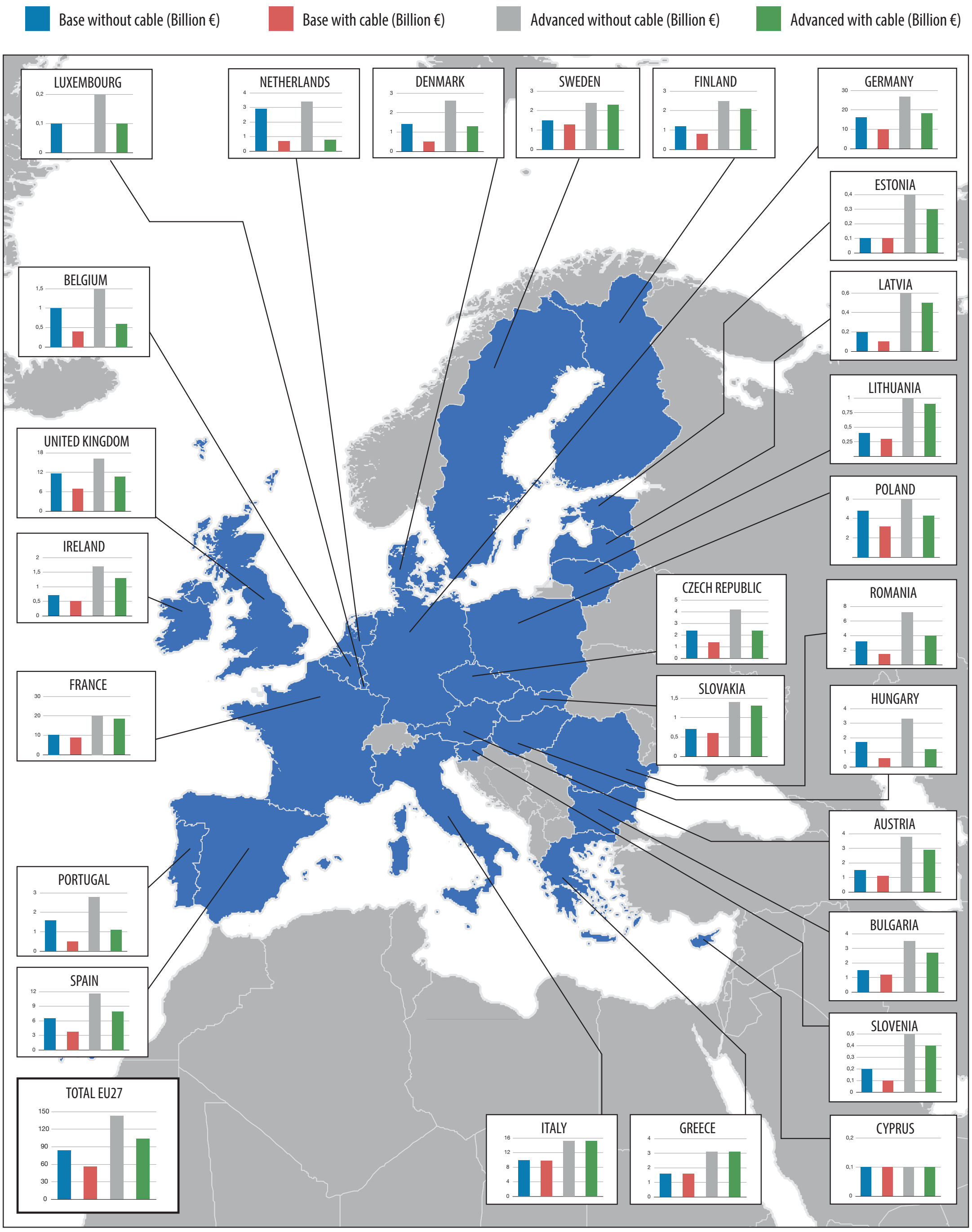
- **Minimum:** Theoretical (advertised) download speed, with Internet centres in rural areas.
- **Base:** Theoretical (advertised) download speed.
- **Advanced:** Actual (guaranteed) download speed.
- **Maximum:** Actual (guaranteed) download and upload speed.

In all scenarios except the first "minimum" scenario, coverage to the household is assumed to be required. These differing scenarios each implied different feasible solutions. For example, the Advanced scenario could be met with ADSL2, LTE, VDSL2, EuroDOCSIS 3.0, FTTB, and FTTH, while the Maximum scenario could be satisfied only with pure fibre solutions.

The EIB analysis considers the incremental cost in each Member State of achieving each of the three DAE objectives under each of the four scenarios. In Figure 25, these costs are presented for each scenario, with and without the use of cable.

76 See Hätönen, J. (2011): "The economic impact of fixed and mobile high-speed networks", in: Productivity and growth in Europe: ICT and the e-economy, EIB Papers, Volume 16, No 2.

Figure 25: Cost of meeting DAE objectives with and without cable in various scenarios



Source: Hätönen (2011).

The use of cable could produce quite substantial cost savings in implementing DAE objectives, on the order of some 30% in overall cost savings in quite plausible scenarios. Innovative technological enhancements to VDSL (vectoring, pair bonding and phantom DSL as described in Section 4.1.1) do not appear to have been considered. Cable is held to produce no savings at all in the Maximum scenario, because cable is felt to be incapable (at present, at least) of providing 30 Mbps, to say nothing of 100 Mbps, of usable symmetric capacity.[77]

In our view, the use of scenarios is appropriate, but it is necessary to temper this use with reasonable expectations as to what European consumers want and need.

First, we question whether Europeans would accept the use of Internet centres (as envisioned in the Minimum scenario), except perhaps in the most exceedingly remote areas. In the developing world, it is common to speak of universal access (at schools, post offices, or libraries) to electronic communication services rather than universal service in the home; however, we do not believe that Europeans would or should accept this. Europeans might perhaps instead accept somewhat lower bandwidth in remote or hard-to-access areas.

Second, as noted in Section 2.3, 30 Mbps of guaranteed symmetric bandwidth seems to be enormously in excess of the average busy hour of residential consumers, even in 2020 and well beyond.[78] Thus, we are of the view that the Maximum scenario represents a very considerable "overkill" relative to realistic needs of European consumers and even well beyond the time horizon envisaged by the DAE.

All of this would tend to suggest that the Minimum and Maximum scenarios can safely be ignored for practical purposes, and that the Basic and Advanced scenarios likely bracket the most realistic measures of the cost of meeting DAE objectives.

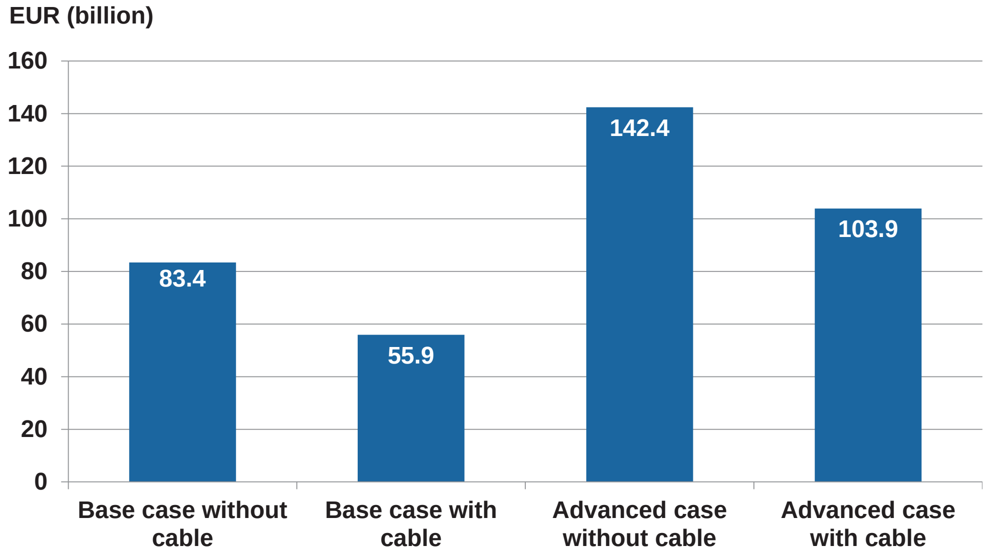
The Basic scenario, where 30 Mbps and 100 Mbps can be interpreted as advertised speeds, are probably somewhat below the level of realistic consumer expectations in 2020, while the Advanced scenario (where the advertised speed must be delivered all the time, but not necessarily in both directions) appears to be greatly in excess of real consumer needs in 2020 and beyond.

The benefits that cable offers across the EU as a whole are substantial.

77 In our view, the long term potential to increase the upstream bandwidth available with cable is significantly underrated by most experts (see Section 5.3.4).

78 Note, incidentally, that contrary what many of us have assumed, the Cisco VNI 2011 analysis finds that Internet data traffic is become less symmetric over time, not more, due to the increased use of video. "With video growth, Internet traffic is evolving from a relatively steady stream of traffic (characteristic of P2P) to a more dynamic traffic pattern. … With the exception of short-form video and video calling, most forms of Internet video do not have a large upstream component. As a result, traffic is not becoming more symmetric as many expected when user-generated content first became popular. The emergence of subscribers as content producers is an extremely important social, economic, and cultural phenomenon, but subscribers still consume far more video than they produce. Upstream traffic has been flat as a percentage for several years "

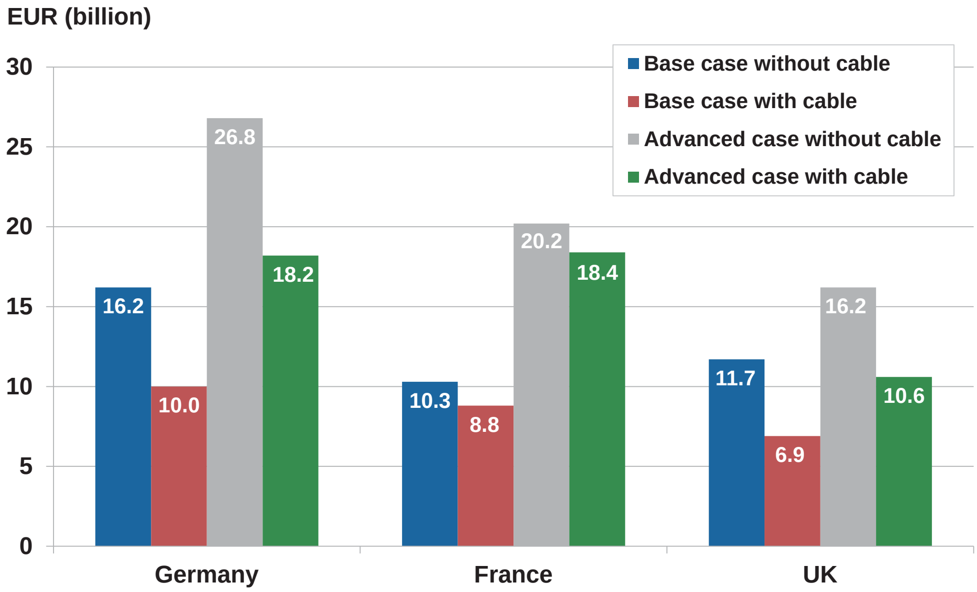
Figure 26: Incremental deployment costs for Europe as a whole, Basic and Advanced scenarios, with and without cable



Source: Hätönen (2011), WIK calculations.

Under the Basic and the Advanced scenarios, the use of cable potentially reduces cost of meeting DAE objectives by up to 30%, with results that differ however among the Member States (largely as a function of the degree to which cable is deployed). A country such as Germany, with a huge number of homes passed by cable, potentially benefits more than a country such as Italy where the cable presence is negligible. Figure 27 depicts incremental deployment costs in Germany (with widespread deployment of cable) in comparison with those of the UK (less deployment) and France (rather little cable). Whether policymakers would prefer to take that “cable dividend” as a cost savings, rather than a gain in facilities-based competition, is a separate question.

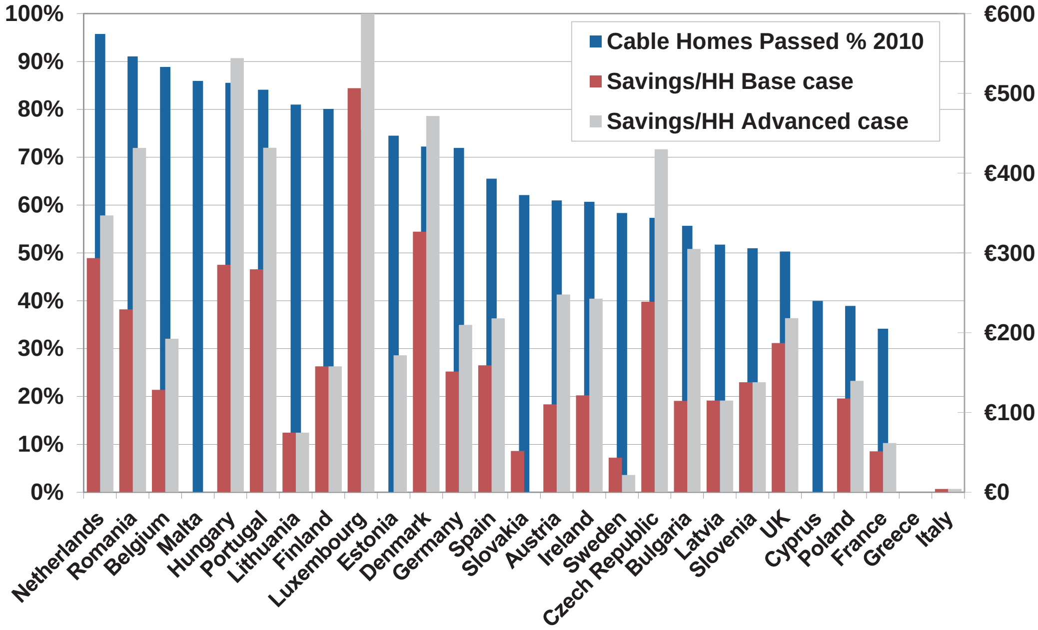
Figure 27: Incremental cost of meeting DAE objectives with and without cable, Basic and Advanced scenarios, in Germany, France and the UK



Source: Hätönen (2011), WIK calculations.

The limitation that cable homes passed places on these savings becomes visible when the data are plotted together.

Figure 28: Cable homes passed, and savings per household in the Basic and in the Advanced scenarios, by Member State



Source: Hätönen (2011), WIK calculations.

It is worth noting that the Feijoo/Gomez-Barroso analysis appears to accord reasonably well with the EIB analysis for Spain. The EIB finds an incremental cost of €11.6 billion to complete the network in Spain in the Advanced scenario (no cable), and €6.5 billion in the Basic scenario (no cable). This corresponds to a Feijoo/Gomez-Barroso estimate of €12.6 billion to complete the network with FTTH, versus €7.7 billion to complete it with FTTC/VDSL. The underlying assumptions are not identical, but our impression is that these findings are surprisingly close.

Feijoo/Gomez-Barroso also found that completing the network with LTE would cost €10.5 billion; however, the more realistic design would use LTE only in low density areas (below 50 inh/Km^2).

7 FACILITIES-BASED INFRASTRUCTURE COMPETITION

Key Findings

Key Findings

- The European Regulatory Framework has always advocated an approach to regulation that is, insofar as practicable, technologically neutral.
- Given this preference of the Regulatory Framework for technological neutrality, and for infrastructure competition, it is striking that the Digital Agenda for Europe contains only a single reference to cable television – and that an altogether backward-looking statement.
- More recent statements from Commissioner Kroes appear to reflect a gradual, welcome shift to a more technologically agnostic posture.
- Cable provides facilities-based infrastructure competition. The value of infrastructure competition is explicitly recognised in the European Regulatory Framework.
- Infrastructure-based competition is important in the long term. A European network environment where only a single medium provides last mile access is a European network environment where detailed regulation to address market power is needed forever.
- Cable tends to enjoy low unit costs in providing broadband services at whatever speed. This puts pressure on incumbents to innovate, and to operate efficiently.
- Infrastructure competition is a valuable complement to SMP-based regulation. For instance, it can help to correct for any errors in regulatory price-setting.
- There are many indications that cable (DOCSIS 3.0) coverage stimulates fixed network operators to deploy fibre-based ultra-fast broadband more quickly.
- A recent analysis of potential NGA deployment in Spain distinguishes between areas of “2+” competition, where the fixed network, cable and mobile all compete, versus “1+” competition, where only fixed and mobile compete. Facilities-based inter-modal competition, even if limited to discrete geographic areas, may have the tendency to constrain prices to reasonable levels across much larger geographic areas.

Policy and regulation in Europe and in Member States alike have put a strong emphasis on the maintenance of procompetitive remedies for fibre-based solutions (FTTN/VDSL, FTTB/FTTH). The results of fibre-based NGA deployment internationally *in terms of competition* have, however, been decidedly mixed to date. NGA deployment in Japan, for instance, has come at the expense of a re-monopolisation of the last mile of the telecommunications network.[79] Deployment of a fibre-based National Broadband Network (NBN) in Australia comes at the expense of inhibiting inter-modal competition in order to ensure that the NBN can be profitable.

7.1 The Regulatory Framework and facilities-based competition

The European Regulatory Framework has always advocated an approach to regulation that is, insofar as practicable, technologically neutral. This is manifest in Article 8 of the Framework Directive, as amended in 2009: "… Member States shall take the utmost account of the desirability of making regulations technologically neutral and shall ensure that, in carrying out the regulatory tasks specified in this Directive and the Specific Directives, in particular those designed to ensure effective competition, national regulatory authorities do likewise."

Article 8(5) goes on to say: "The national regulatory authorities shall … apply objective, transparent, non-discriminatory and proportionate regulatory principles by, inter alia: … safeguarding competition to the benefit of consumers and promoting, where appropriate, infrastructure-based competition; …"

The Regulatory Framework as enacted in 2002-2003 is, moreover, grounded at its core in the belief, or at least the hope, that increasing competition would in time obviate the need for regulation that primarily responds to the presence or absence of *Significant Market Power (SMP)*.

Yet last mile market power will not disappear unless there is infrastructure-based competition. The DAE speaks of the need for "… providing the right incentives to stimulate private investment, complemented by carefully targeted public investments, without re-monopolising our networks"; however, it seems to disregard any concerns that a European network environment where only a single medium provides last mile access is a European network environment where detailed SMP-based regulation is needed forever.

Given this preference of the Regulatory Framework for technological neutrality, and for infrastructure competition, it is striking that the Digital Agenda for Europe contains only a single reference to cable television – and that an altogether backward-looking statement.[80]

The absence of cable from the initial DAE documents is not a particular cause for concern, because cable does not require public support to meet DAE objectives within its existing footprint. The cable industry can finance these upgrades itself, without public funding. The observation, rather, is that the degree to which cable (and to some degree wireless) was historically overlooked in the DAE from a planning perspective is striking, and seems out of step with the overall European Regulatory Framework.

79 Both NTT East and West have an FTTB/FTTH market share of more than 95% in their respective geographical footprints.

80 Section 2.4.2: "Today in Europe internet access is mainly based on the first generation of broadband, meaning internet accessed over legacy telephone copper and TV cable networks."

The Commission, to its credit, seems to be gradually moving on in its thinking. In a recent speech, Commissioner Neelie Kroes said: “The Digital Agenda has set out some very clear targets on broadband access: wireless helps deliver them. Already, wireless solutions are essential for getting basic broadband to those in rural areas where wired is not an option. But beyond that, I want every European to have 30 Megabit coverage by 2020: and that’s where next generation wireless networks will play a very important role. Already today, in some places, 4G offers those speeds – if not higher. I also want at least half of Europeans to have ultra-fast access at over 100 Megabits by 2020: again, it is clear that no single technology will deliver this, no single magic potion will get us there overnight. We rather need an intelligent mix of complementary technologies, deployed incrementally, and according to local circumstances. Such technologies include in particular Fibre-to-the-Home, upgraded Cable, Fibre-to-the-Cabinet and LTE.”[81]

In a more recent major policy statement, Commissioner Kroes went on to say: “We should be wary of picking winners. ‘Technology neutrality’ is just another way of saying that we cannot predict with any certainty what the best technological solutions will be, nor how they will compete and interact … for example, new technology combining fibre and copper, or upgrading TV cable, can be very cost-effective in delivering higher download capacity.”[82]

7.2 Societal welfare benefits from facilities-based competition

The values of competition are well recognised in the economic literature, and are a cornerstone of the European Regulatory Framework for Electronic Communications. Competition tends to promote lower prices for consumers, greater consumer choice, and incentives for service providers to operate efficiently and to innovate.

Cable provides *facilities-based infrastructure competition*, in contrast to the competition provided by means of regulatory remedies based on Significant Market Power (SMP) under the Framework. The value of infrastructure competition is already explicitly recognised in Article 8 of the Framework Directive, which establishes the high-level regulatory principles that National Regulatory Authorities (NRAs) are to follow. “The national regulatory authorities shall … apply objective, transparent, non-discriminatory and proportionate regulatory principles … safeguarding competition to the benefit of consumers and promoting, where appropriate, infrastructure-based competition …”[83]

Facilities-based competition from cable is not sufficient to enable lifting of regulation from telecommunications incumbents, but it is a valuable complement to traditional regulatory mechanisms. Notably, since facilities-based competition is market-based, and does not depend on regulated prices, it can help to correct any possible errors that might be made in regulatory price setting.

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81 “Neelie Kroes Vice-President of the European Commission responsible for the Digital Agenda Giving Europe a Mobile Broadband Boost,” 2012 Mobile World Congress Barcelona, 27 February 2012, available at: http://europa.eu/rapid/pressReleasesAction.do?reference=SPEECH/12/124.

82 ”Enhancing the broadband investment environment”, 12 July 2012, at: http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/12/554&format=HTML&aged=0&language=EN&guiLanguage=en.

83 Article 8(5)(c).

Cable tends to enjoy low unit costs in providing broadband services at whatever speed. This puts pressure on incumbents to innovate, and to operate efficiently.

7.3 Facilities-based competition as a stimulus for fibre-based NGA deployment

It has long been assumed that the presence of cable serves to stimulate fixed telephony network operators to deploy fibre-based ultra-fast broadband. This is perhaps most visible in the statements of market players themselves.

KPN's focus on fibre deployment has been widely viewed as a response to cable, and their annual report offers confirmation. "In the Dutch broadband market KPN is competing with cable companies and other parties for customer base and market share. The roll out of the fibre network is one of the key elements in KPN's broadband strategy, while the existing copper network is being upgraded."[84]

In Germany, Deutsche Telekom writes: "… Cable network operators are no longer small players. They acquire every second new customer. … Therefore, we do not want to remain idle. For one thing, we will build our network further out, so as to ensure that we can offer our customers the best service quality. In doing so, we have fastened on the right technology mix of (V)DSL and glass fibre, but also mobile broadband technologies such as LTE."[85] They go on to provide concrete examples of their intent to threaten the core business of cable operators, including an agreement with the building management firm Deutsche Annington Immobilien AG to deploy glass fibre to 171,000 households throughout Germany.

A few years ago, Swisscom's CEO said: "We have to some extent lost a lot of customers to cable companies. I am not just talking about Cablecom, but also about the small municipal firms. Some of them have a market share of more than 50%. They are doing a very good job. We have to oppose them by investing in highly capable infrastructure. QUESTION: What technology do you envision? ANSWER: Especially glass fibre. In recent years, we have progressively replaced copper lines with fibre."[86]

There are also suggestions in the literature that this relationship could be demonstrated empirically.[87]

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84 PN Annual Report for 2010, page 41.

85 See „Telekom bringt Wettbewerb in Monopolstrukturen", 16 August 2012, available at: http://blogs.telekom.com/2012/08/16/telekom-bringt-wettbewerb-in-monopolstrukturen/. "Auch auf diesem Markt sind die Kabelnetzbetreiber keine kleinen Spieler mehr: Jeder zweite Neukunde geht inzwischen an sie. Da wollen wir nicht untätig bleiben. Zum einen bauen wir unsere Netze weiter aus, um sicherzustellen, dass die Kunden bei uns die beste Übertragungsqualität geboten bekommen. Dabei setzten wir auf den richtigen Technologie-Mix aus (V)DSL und Glasfaser, aber auch mobilen Breitbandtechnologien wie LTE."

86 Interview with Swisscom CEO Carsten Schloter, Edition 28/2008: Die Weltwoche, "Wir haben ja teilweise massiv Kunden an die Kabelanbieter verloren. Ich spreche nicht nur von Cablecom, sondern auch von den kleinen städtischen Anbietern. Gewisse städtische Netzbetreiber erreichen Marktanteile von über 50 Prozent. Die machen einen sehr guten Job. Da müssen wir dagegenhalten und in eine leistungsfähige Infrastruktur investieren. FRAGE: Auf welche Technologie setzen Sie bei diesem Ansinnen? ANTWORT: Vor allem auf das Glasfaserkabel. In den vergangenen Jahren haben wir immer mehr Kupferleitungen durch Glasfasern ersetzt."

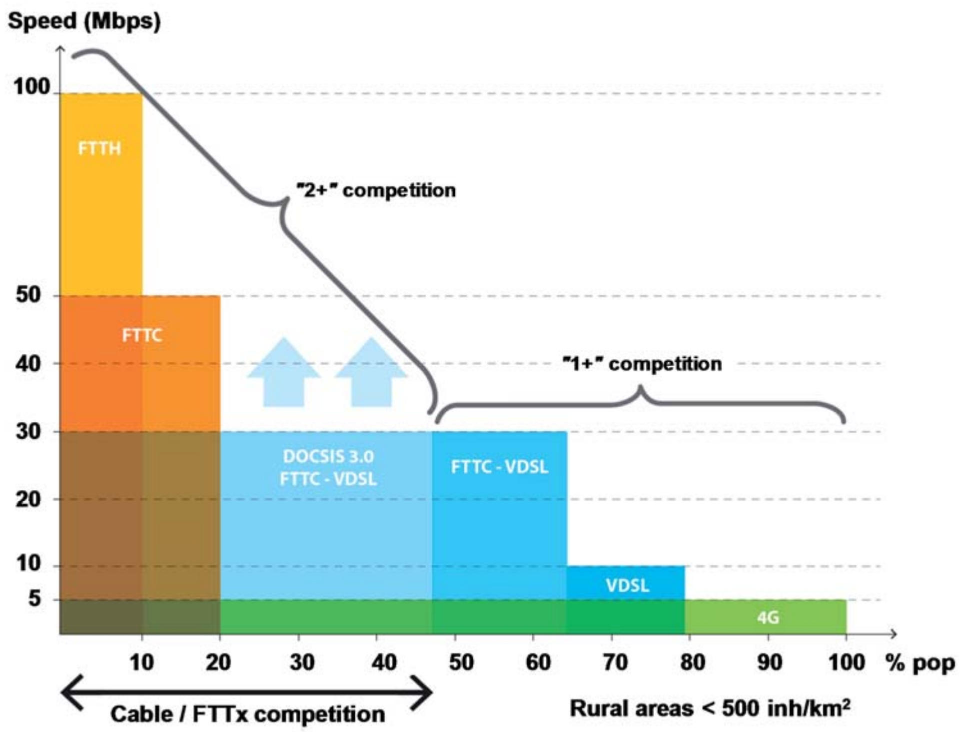
87 See for instance Kiesewetter, W., Lucidi, S., Neumann, K.-H., and U. Stumpf (2012): "NGA Progress Report", WIK, 1 March 2012.

7.4 Prospects for achieving sufficient facilities-based competition

Deployment of a mix of technologies has the benefit of enabling inter-modal facilities-based competition in broadband markets.

A recent analysis of potential NGA deployment in Spain (see Figure 29)[88] distinguishes between areas of "2+" competition, where the fixed network, cable and mobile all compete, versus "1+" competition, where only fixed and mobile compete. Facilities-based inter-modal competition, even if limited to discrete geographic areas, may have the tendency to constrain prices to reasonable levels across much larger geographic areas.

Figure 29: Facilities-based competition and NGA deployment



Source: Feijoo and Gomez-Barroso (2010a).[89]

88 Feijoo, C., Gómez-Barroso, J.-L., Ramos, S. and R. Coomonte (2011a); and Feijoo, C. and J.-L. Gómez-Barroso (2010b).

89 Feijoo and Barroso, op. cit. Note that the figure shows a maximum speed of 30 Mbps because that was the highest cable broadband speed on offer in Spain at the time; today, however, cable broadband offers of 100 Mbps or more are commonplace in many European countries.

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