

Hätönen, Jussi

**Article**

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## ABSTRACT

*Europe is lagging behind other developed economies in the availability and use of very fast broadband services. The recently introduced Digital Agenda for Europe initiative sets forward ambitious targets for the development of super-fast broadband infrastructures in Europe to foster smart and sustainable growth. This paper presents estimates of the costs of meeting these targets through the deployment of next-generation networks. Furthermore, the magnitude of the financing gap is estimated and public support mechanisms are discussed to complement market investment in areas with low financial viability for the investment. The rationale of public sector support is discussed in light of the expected economic benefits of NGNs to consumers and businesses.*

**Jussi Hätönen** ([hatonen@eib.org](mailto:hatonen@eib.org)) is an Economist with the Project Directorate (Digital Economy and Education Division) of the European Investment Bank. The views expressed in this article are those of the author and do not necessarily reflect those of the EIB.

# The economic impact of fixed and mobile high-speed networks

## 1. Introduction

With over 2 billion subscribers worldwide, the Internet has become a necessity of modern societies. Along with the growth of use, Internet has evolved into an important economic activity. In fact, with an average 3.4 percent contribution to GDP, Internet-related activities have already a greater weight than education (3.0 percent), agriculture (2.2 percent) or utilities (2.1 percent), and an only slightly smaller weight than, for example, transportation (3.9 percent). Furthermore, it is estimated that Internet has contributed to 21 percent of GDP growth in the last five years in advanced economies (Rausas *et al.* 2011). In several countries, Internet is in fact classified as a universal service. Accordingly, network operators are obliged to provide this service to every inhabitant similar to electricity and roads.



Jussi Hätönen

Internet has evolved greatly since its introduction at the beginning of the 1990s, driven by developments in network technologies constantly allowing new services and solutions to be provided over the Web. In the past few years there has been increasing discussion on what is referred to as next generation Internet networks. Next generation access networks (NGN or NGA) refer to mobile and fixed-line networks enabling much higher access speeds than “traditional” networks. In Europe this discussion was recently further accelerated by the introduction of the Digital Agenda for Europe, one of the seven flagship initiatives of the Europe 2020 strategy and which puts forward ambitious targets calling for development of next generation super high-speed networks in the EU. The justification of these networks is often wrapped around economic benefits. Friedrich *et al.* (2009), for instance, state that “next generation national broadband networks can significantly improve the way that consumers, businesses, and governments interact, spurring economic growth and productivity”, and that “governments must play a role in the deployment of such networks to overcome the hurdles that cannot be addressed by the private sector”. In fact, it is widely acknowledged that due to the high cost of deploying NGNs, a high level of public support and intervention is called for. Policy makers have, in light of the Digital Agenda, initiated a discussion on how the governments should support the deployment of such networks – basing the need for them on high expected economic benefits.

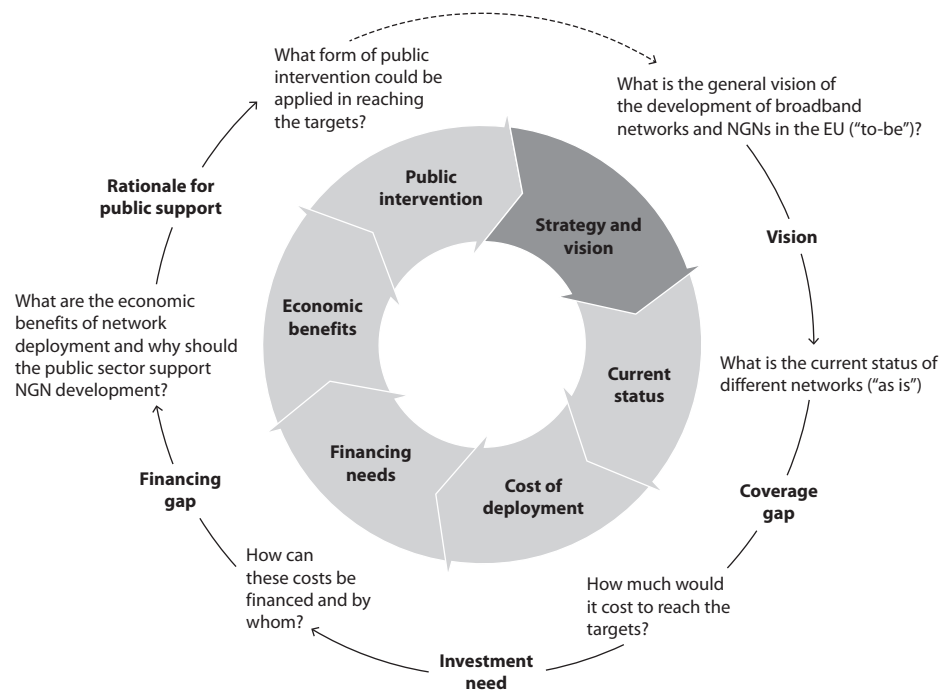
Despite an extensive literature on NGNs, much still remains unknown. Firstly, in the context of the EU, some initial attempts have been made to assess the total cost of implementing the Digital Agenda targets, yet they have mainly focused on a single technological scenario building on aggregate level statistics – therefore falling victim to overgeneralizations in the assessment. Secondly, and partly related to the lack of existing knowledge of the cost of deployment, there have been only limited attempts to identify the financing gap and accordingly, to put the claims for public support for deployment on a sound economic basis. Thirdly, despite wide existing research on the economic impact of telecommunications and the Internet, it remains to a large extent unclear what the particular benefit is for consumers of having super high-speed access at home through NGNs, that is: What is the added economic benefit of upgrading from basic broadband connections?

The purpose of this paper is to address these shortcomings. The paper is structured as illustrated in Figure 1. Firstly, the assessment of broadband infrastructures and development of NGNs in particular cannot be disconnected from the underlying technologies – that is: What are NGNs and how do they differ technologically from other network infrastructures? The answers to these questions, given in Section 2, are imperative as they drive technical alternatives, further impacting on the deployment cost and the assessment of financing gaps and economic returns. Then, an overview and discussion on the Digital Agenda targets are provided, as these targets are likely to provide the main policy

**With the EU Digital Agenda as a benchmark, this paper assesses investment needs and the market shortfall in financing.**

reference for NGN development in Europe in the coming years (Section 3). Once the vision set in the Digital Agenda has been clarified (“to-be” state), the current state of network infrastructures (“as-is” state) is assessed to identify the coverage gap (Section 4). Once the gap has been identified, a deployment cost assessment can be made, thereby identifying the financing needs (Section 5). This is followed by the assessment of market shortfall in financing such network deployments and the need for public intervention, also touching on issues such as customers’ willingness to pay (Section 6). To assess the justification of public intervention, it needs to be assessed whether the economic benefits of NGNs actually outweigh the cost of deployment (Section 7). A discussion on potential mechanisms for public intervention is provided in Section 8. Finally, Section 9 offers a summary of the main results and some insights for policy makers.

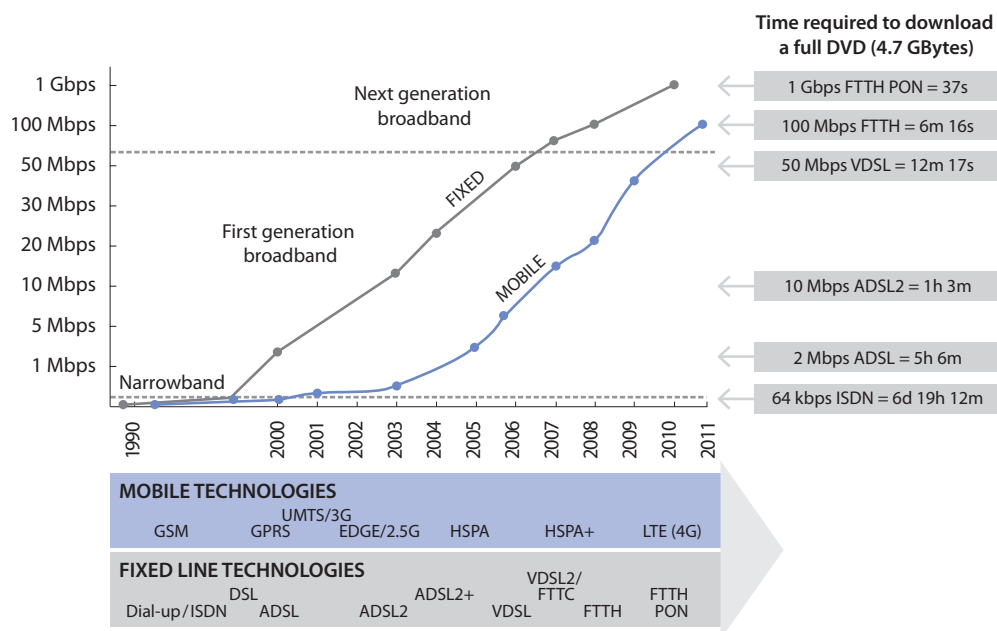
**Figure 1. Structure of the paper and research questions**



**2. Network generations: What is the next generation in broadband networks?**

The telecommunications standardization body of the International Telecommunications Union (ITU-T) defines next generation network as “a packet-based network able to provide services including telecommunication services and able to make use of multiple broadband, quality of service-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It offers unrestricted access by users to different service providers. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users.” This engineering-driven definition does not provide much to work with in assessing the economic aspects of these networks. In more general terms, NGNs refer to very high speed or super high speed broadband networks, often referring to fibre-based technologies in fixed line and 4<sup>th</sup>-generation networks in mobile. As opposed to basic broadband Internet connections, defined by the OECD in 2006 as having download data transfer rates equal to or faster than 256 kbit per second (kbps), with respect to NGNs, the discussion is often on access speeds beyond 50 Mbps – over 200 times the speed of basic broadband. Figure 2 provides a broad illustration of the evolution of access speeds and the corresponding evolution of fixed and mobile network technologies between 1990 and 2011.

**Figure 2. The evolution of broadband access technologies and speeds between 1990 and 2011**



Notes: Figure 2 is an illustrative description of the evolution of broadband access technologies and speeds. The access speeds refer to reported download speeds.

The term “next generation network” derives from the historical developments of broadband technologies. Both fixed and mobile technologies have evolved significantly since the late 1980s and early 90s, a time when the first dial-up (ISDN) Internet connection became available over telephone lines and the first GSM mobile networks were introduced. In the second half of the 1990s, digital subscriber line (DSL) technology was introduced, initially providing some 200 kbps access speeds but the importance was in paving the way for further development of the ADSL technology, which enabled access speeds from 2 Mbps (ADSL) all the way to 24 Mbps (ADSL2+) today. In the mobile arena, the first data networks (GPRS, UMTS and EDGE) deployed after the turn of the millennium provided access speeds up to 600 kbps. However, it was the HSPA technologies first introduced in 2005 that really enabled transfer of data in mobile networks. The first HSPA networks enabled data transfer speeds of 2 Mbps, but currently the evolutions of this technology allow theoretical speeds close to 50 Mbps. To put these access speeds into perspective, Figure 2 also illustrates the time required to download a full DVD movie from the Internet with certain fundamental access speeds. With an early 64 kbps ISDN connection, the download would have taken close to 7 days and with a 2 Mbps ADSL access still common among households, the download would take over 5 hours, but with an access allowing 100 Mbps (fibre or LTE), the download would only be a matter of a few minutes.

These technologies allowing super-high access speeds are often referred as next generation networks (NGNs). In fixed line broadband, DSL and its gradual developments (ADSL, ADSL2, and ADSL2+) are seen as the first-generation broadband, replacing narrowband dial-up Internet connections. Although significant efforts are still put into increasing the possible access speeds in the copper line network, the next generation often refers to fibre-based technologies, where the fibre is deployed to the curb (VDSL/FTTC), building (FTTB) or all the way to the customer (FTTH – fibre to the home). In the mobile arena, NGNs are often used to describe long-term evolution (LTE) networks, while the existing High Speed Packet Access (HSPA) technology and its evolutions, although considered as third-generation (3G) mobile technologies, are considered as the “first” generation broadband (Friedrich *et al.* 2009). What is common in both cases is that NGNs require new infrastructures to be deployed as opposed to

***NGNs require massive investment in new infrastructure, be it in the fixed-line or in the mobile arena.***

upgrading the electronic components or software of existing infrastructures. Therefore, the deployment of such networks imposes a great financial stretch to the industry, as the upgrade to NGNs is completely different from prior upgrades of copper and cable infrastructures. Rather than swapping equipment at either end of an existing access network, fibre requires building an entirely new network, which inevitably makes the upgrade much more expensive. Thus, together with the high cost, the issue of the economic value added of NGNs is constantly discussed.

### 3. The Digital Agenda for Europe initiative

Through the presentation of the Europe 2020 Strategy<sup>1</sup>, the European Commission acknowledged the economic and social benefits from a Digital Single Market based on fast and ultra-fast Internet and interoperable applications. In this communication the European Commission launched the Digital Agenda (DA) for Europe, one of the seven flagship initiatives introduced to foster smart, sustainable and inclusive growth in the EU. With respect to the development of broadband infrastructures in the EU, it stated three concrete targets:

- **Target 1:** to bring basic broadband access for all Europeans by 2013;
- **Target 2:** to enable access to much higher Internet speeds (30 Mbps or above) for all Europeans by 2020; and
- **Target 3:** to ensure that 50 percent or more of European households subscribe to Internet connections above 100 Mbps by 2020.

*Investment needs depend on the interpretation of the EU targets relative to access speed, point of access and whether the targets refer to each and every member state.*

To reach these ambitious targets, the existing broadband network infrastructure needs to be extended by a smart mix of wireless and wire-line technologies. However, these targets, as they are formulated, remain open to further interpretations. Firstly, what is the definition of “basic broadband” in Target 1? For instance, while OECD defines broadband as having access speeds of 256 kbps and above, and some instances define even lesser thresholds, in current times basic broadband commonly refers to access speeds above 1 or 2 Mbps. Secondly, what is actually meant by Targets 2 and 3? Are the threshold speeds simply download or do they entail upload as well (symmetric or asymmetric), and are speeds guaranteed/actual speeds, advertised, theoretical speeds? While certain technologies are good in providing very fast download speeds they suffer from technological constraints to provide similar upload speeds. Also, theoretical speeds are typically much bigger than advertised speeds, which again are higher than actual user experience. Thirdly, what is the definition regarding the level or point of access? Does the definition of “have access to” refer to the workplace, village, building passed, home passed, etc.? For instance, a home connected to the Internet is different from a home passed by the Internet, just like a home connected to the road network has a driveway and is thus different from a road passing the home. Finally, what is meant by 50 percent of European households in Target 3 – is it the pan-EU average or each of the 27 national averages? If the former is meant, for instance, Target 3 could be reached by only covering the biggest cities of Europe with super-fast broadband irrespective of their country.

The way the DA targets are interpreted affects the scale and the type of available technologies to be deployed, which, in turn, has huge implications for the total required investment. In the methodology to address the total cost of fulfilling the DA targets discussed in Section 5 below, the different interpretations are built into different scenarios to quantify the total cost of different possibilities.

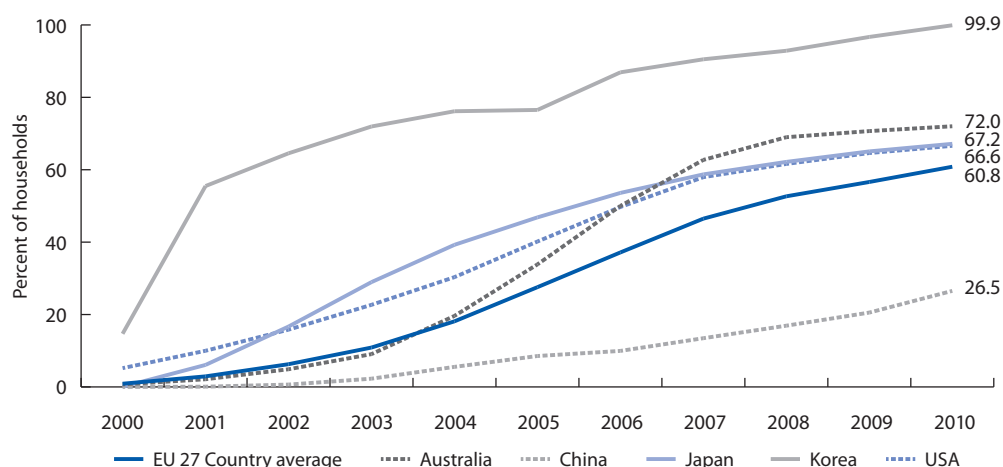
<sup>1</sup> Europe 2020: a European strategy for smart, sustainable and inclusive growth.

#### 4. The current broadband environment in Europe

To gain a better understanding of the magnitude of investment required to fulfil the DA targets, the current broadband environment in Europe needs to be looked at. At the end of 2010, the broadband household penetration (*i.e.* the share of households actually subscribing to broadband service) in EU countries reached 60.8 percent (simple average of national penetration rates) (Figure 3). This is below the penetration rates of other developed nations such as the US (66.6 percent), Australia (72.0 percent) and Japan (67.2 percent), and well below technology leaders such as Korea with 99.9 percent household broadband penetration. China is still lagging behind in this respect with only a 26.5 percent household broadband penetration, but it has shown accelerating growth in the past few years. At the end of 2010, the broadband penetration in EU-15 countries was 67.9 percent of households, while in the new member states, the penetration was 52.0 percent.

**At 61 percent on average, EU countries had lower broadband household penetration than other developed nations in 2010.**

Figure 3. Broadband household penetration in EU and comparison



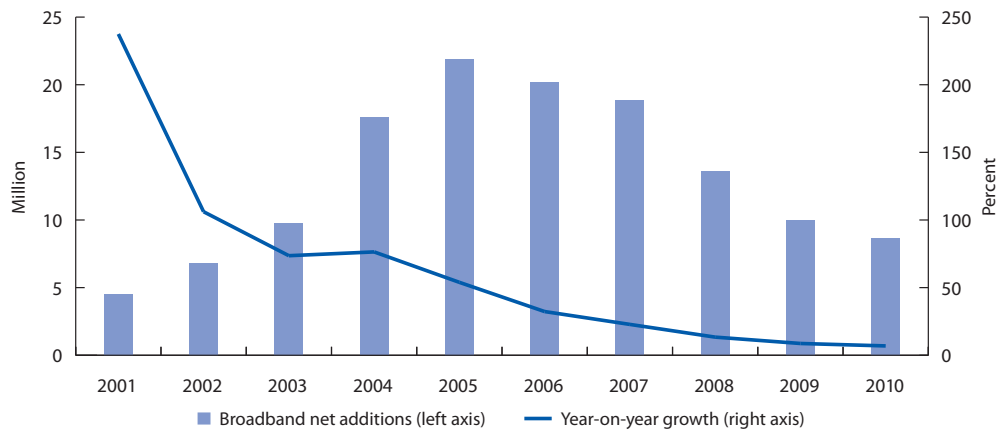
Source: World Broadband Information Service (WBIS)

Note: The WBIS does not provide a clear definition of broadband, but the latter can be seen as referring to Internet connections with access speeds above 150 kbps.

In respect of broadband technologies, xDSL (including all the different DSL evolutions discussed above) is the most used access medium, accounting for 64.4 percent of all broadband connections in the EU and connecting close to 40 percent of EU households to broadband Internet. Cable accounts for 21.2 percent of all broadband connections with a household penetration of 13 percent. FTTx technologies account for 8.7 percent of broadband connections and a household penetration of 5.6 percent. Other access domains (including powerline, fixed-wireless, WiMax and Ethernet UTP/FTP) account for 5.7 percent of connections, corresponding to household penetration of just over 3 percent. Accordingly, fibre-based NGNs currently account for less than 10 percent of all broadband connections.

The growth momentum of broadband penetration has been steadily declining in the past years, as is illustrated in Figure 4. For instance since 2005, representing the highest growth year in absolute net additions, the absolute net additions have dropped from 21.9 million to 8.7 million in 2010, and the relative growth dropped from 53.9 percent in 2005 to 6.9 percent in 2010. This illustrates early signs of market maturity. However, the household penetration rates above 80 percent in the Netherlands and Denmark for instance, and still continuing growth in these markets, indicate as an example that there is still room for improvement if demographic and technical challenges can be overcome.

**Figure 4. Absolute and relative growth of broadband subscriptions in the EU**

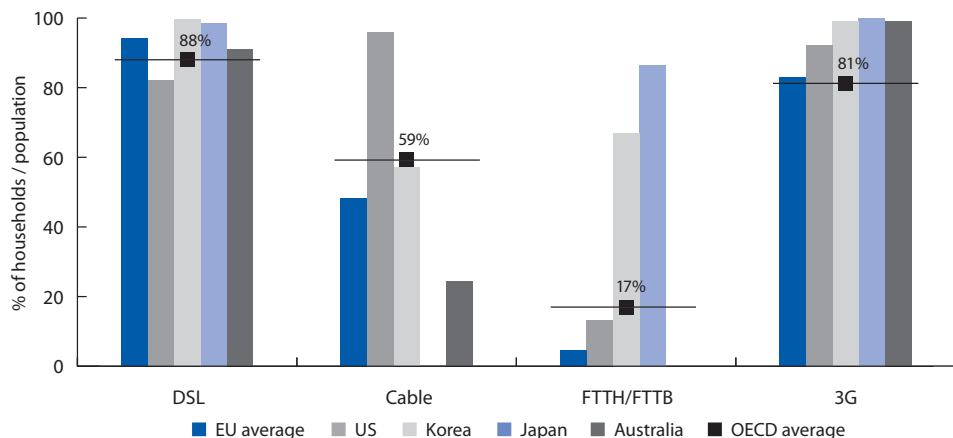


Source: WBIS

**Coverage gaps are largest for the fastest broadband connections (cable and fibre to the curb/building/home).**

While the penetration of broadband is the key determinant in generating economic return, in assessing the total cost of deployment, it is the total coverage of different broadband technologies that matters. Coverage reflects the availability of service, not uptake, and is therefore inherently greater than penetration. Apart from xDSL and 3G, Europe is lagging behind the OECD average regarding the coverage of different broadband access technologies (Figure 5). In particular, European countries are trailing other developed countries and technology leaders such as the US, Japan as well as Korea in coverage of access technologies allowing very high broadband access speeds, namely cable and FTTx technologies. For instance, while the OECD average for FTTx coverage is 17 percent, the EU average is only 4.5 percent. Similarly, at 48 percent, cable coverage, which can allow very fast broadband speeds, is below the OECD average.

**Figure 5. Coverage of different broadband access technologies in selected countries**



Source: OECD (2010)

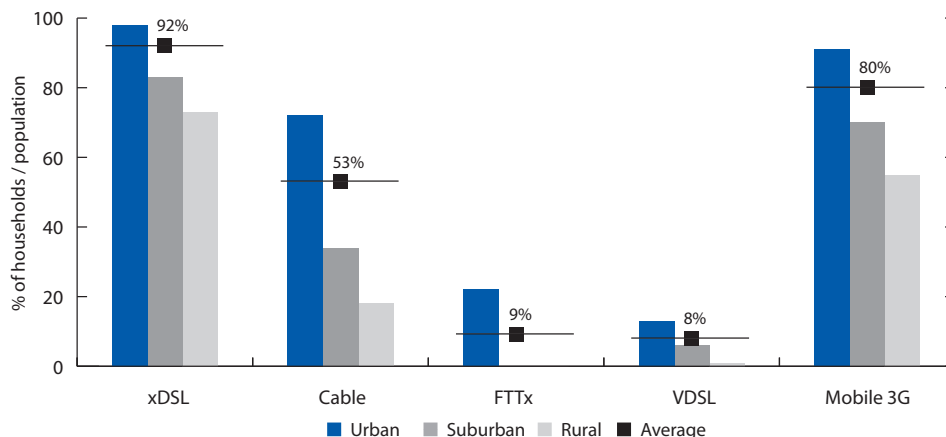
Notes: EU in this figure refers to the 21 EU countries that are members of the OECD. The data are gathered from various sources by OECD and in some cases rely on different periods, causing certain issues of comparability with e.g. the WBIS data.

In the EU-27, the total broadband coverage with different technologies is as follows (averaged by country): xDSL 92 percent of all households, cable 53 percent, FTTx 9 percent, VDSL 8 percent, and mobile 3G 80 percent. The big challenge for broadband availability in the EU seems to lie in the more remote and particularly rural areas. For instance, as shown in Figure 6, xDSL coverage in urban areas



is 98 percent of households, while the coverage is only 73 percent in rural areas. Moreover, with respect to cable, urban areas have coverage of 72 percent while rural areas have only 18 percent, and the existing FTTx deployments seem to have focused on the urban areas only, providing a total coverage of 22 percent of the European urban households.

**Figure 6. Coverage of different broadband access technologies in the EU and demographic breakdown**



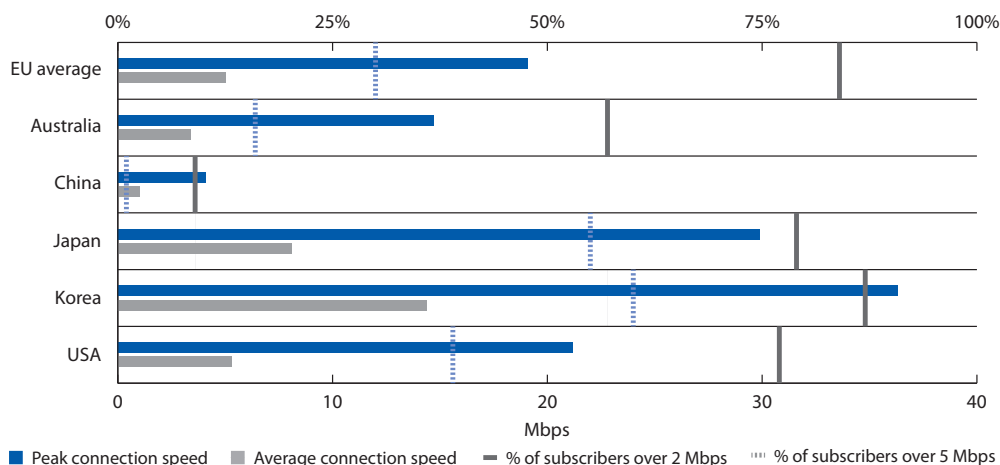
Source: iDATE; national statistics

Notes: Urban = more than 500 inhabitants per km<sup>2</sup>; Suburban = between 100 and 500 inhabitants per km<sup>2</sup>; Rural = less than 100 inhabitants per km<sup>2</sup>. The minor discrepancies between the coverage data represented in Figures 5 and 6 are due to data source differences. Also, Figure 5 only includes European countries belonging to the OECD, while Figure 5 includes all EU-27 countries.

The average broadband access speeds in the EU reflect a lack of high-speed network infrastructures. According to a recent study (Akamai 2011), the average connection speed for an average broadband subscriber in the EU is 5.0 Mbps, ranging between 3.5 and 7.5 Mbps between countries. In the US, the average speed is only slightly higher (5.3 Mbps), but in Japan (8.1 Mbps) and Korea (14.4 Mbps), average broadband speeds are significantly higher (Figure 7). In the EU, the average peak connection speed is 19.1 Mbps, ranging between 13.9 and 32.7 Mbps. Although this is somewhat irrelevant in respect of the actual user experience, it illustrates the access speed capabilities of the network. 84 percent of the broadband connections are above 2 Mbps, one of the highest shares in the world, whereas only 30 percent is above 5 Mbps. As a consequence, the EU is trailing behind other developed broadband markets such as the US, Japan and Korea in terms of connections faster than 5 Mbps.

*Average access speeds in the EU reflect a lack of high-speed network infrastructure.*

**Figure 7. Connection speeds in the EU and selected countries**



Source: Akamai (2011)

***It will be challenging to bring Europe to the level of other digitally developed nations in terms of very high-speed broadband.***

Therefore, it seems it will be a huge challenge to bring the European broadband markets to the level of other digitally developed nations in respect of availability and use of very high speed broadband. In addition to the need of increasing the availability of basic broadband in rural areas to bridge the digital divide (Target 1 of the DA), the EU would have to catch up in the provision of network infrastructures allowing very high and super high-speed broadband in order to meet Targets 2 and 3 of the DA. However, increasing network coverage does not lead to a one-to-one increase in the uptake of the service, as there exists an inherent demand-supply gap in the provisioning of broadband services. For instance, while more than 90 percent of EU households have currently access to xDSL broadband, just over 60 percent of households are actually subscribing to the service (Figures 6 and 3). The demand-supply gap for super-fast broadband access is likely to be greater still, particularly due to low perceived value in addition to basic broadband and therefore lacking willingness to pay more for the service. This will be discussed further in Section 7.

## **5. The cost of reaching the Digital Agenda targets**

Between July 2010 and March 2011, the European Investment Bank (EIB) commissioned a study with the aim to assess the cost associated with the DA broadband targets. While earlier attempts to quantify this focused on the investment needs to reach full European coverage with fibre-based networks (e.g. OECD 2009), often relying on pan-EU averages, the approach in this study is technology neutral, applying a mix of available technologies to meet the targets at different access speeds. The assessment in this study follows a bottom-up approach – building from country level assessments to an aggregate EU total.

### **5.1 Methodology**

In order to maximise the flexibility of the approach, the DA targets in the study are interpreted in different ways, resulting ultimately in four different scenarios. While all of them fulfil the targets set out by the European Commission, the quality requirements vary extensively. The scenarios reflect the following underlying base assumptions: Coverage (not penetration) is the benchmark infrastructure variable; certain niche technologies are excluded (e.g. Satellite and WiMAX); the focus is on residential broadband access; competition is not considered, thus a single platform is modelled; and regulatory parameters are not accounted for. Specifically, for Target 1 it is defined that the basic broadband threshold is 1 Mbps, and for Target 3 it is assumed that a coverage of 50 percent of households needs to be achieved for each member country.

As regards the definition of deployment unit costs for each technology, industry benchmarks combined with EIB experience were used. Deployment unit costs for each technology were then adjusted with population density. For the purpose of the cost analysis, countries were split into urban (more than 500 inhabitants per km<sup>2</sup>), suburban (between 100 and 500 inhabitants per km<sup>2</sup>) and rural (less than 100 inhabitants per km<sup>2</sup>) areas, since population density is the key determinant of deployment unit costs. This distribution was made based on the availability of coverage information of different broadband technologies. Ultimately, NUTS-4 level granularity<sup>2</sup> in population density and existing broadband coverage was applied. Further, different technologies were adjusted with a labour cost variable as the labour intensity of deployment varies across technologies. Several other variables affecting cost such as duct availability and terrain type were not included in the cost modelling due to a lack of EU-wide comparable data.

<sup>2</sup> NUTS is the EU's Nomenclature of Territorial Units for Statistics. NUTS-4 (recently renamed into LAU-1) corresponds to local administrative units above the municipal level but much finer than the regional or county level.

The scenarios assume different speed requirements (theoretical/advertised, actual, symmetric) and access requirements (household access or communal access). These scenarios are shown below with an illustration of a set of technologies to be deployed to fulfil all the three targets:

- **Minimum:** Theoretical download speed, with Internet centres in rural areas
- **Base:** Theoretical download speed, coverage of the household
- **Advanced:** Actual download speed, coverage of the household
- **Maximum:** Actual symmetric download and upload speed, coverage of the household

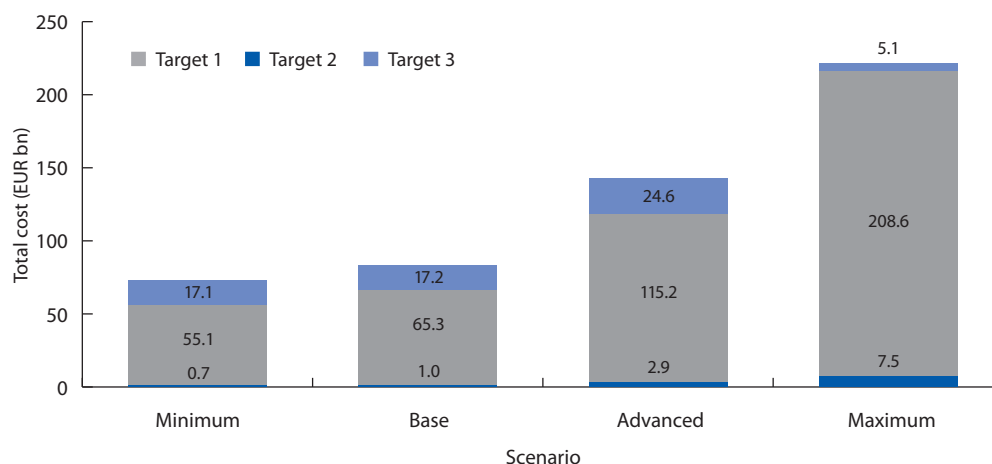
Every target in each scenario for each area leads to a range of available technological solutions, creating a three-dimensional framework for the cost analysis. The technology with the lowest unit cost to fulfil the requirements is applied. In addition, the application of cable infrastructure is analysed separately due to a lack of information on the quality of the existing cable infrastructure in Europe. This creates an additional fourth dimension to the analysis, which is not discussed in detail in this paper.

## 5.2 Results

Based on the methodology summarised above, the study finds that the total cost of implementing all three DA broadband targets varies between EUR 73 and EUR 221 billion. Fulfilling Target 1 requires between EUR 1 billion and EUR 7 billion. Fulfilling Target 2 requires between EUR 55 billion and EUR 209 billion, representing 76 percent to 94 percent of total cost, the proportion being higher in scenarios with higher quality requirements. Fulfilling Target 3 requires between EUR 5 and EUR 25 billion. The low amounts required for Target 3 are due to the cumulative deployment approach, whereby the target can be achieved basically by upgrading the infrastructure deployed for the purpose of Target 2. Total costs across scenarios and split by targets are presented in Figure 8.

If existing cable coverage were considered as fully broadband enabled and upgradeable technology, the total cost would decrease by roughly 30 percent in the minimum, base, and advanced scenarios. In the maximum scenario, there would be no difference, as high symmetric service quality requires fibre deployment.

**Figure 8. The total cost of fulfilling the Digital Agenda broadband targets in different scenarios**



***While stricter interpretations of the EU broadband targets imply a much higher total cost and a larger cost share falling on rural areas...***

When the total cost in each scenario is broken down by demographic areas (based on population density), the urban share of the total investment need decreases as scenarios become more ambitious, while the rural percentage increases. For instance, in the minimum scenario, total-cost shares are approximately 5 percent for rural, 47 percent for suburban and 48 percent for urban areas, respectively, whereas in the maximum scenario, rural areas account for 45 percent of the total cost, suburban areas for around 32 percent and urban areas for the remaining 23 percent.

When the total cost of the maximum scenario is further broken down by individual DA targets, the rural percentage of target cost decreases when moving from Target 1 towards Target 3 while the urban percentage increases. This is not surprising since in practice, Target 3 is primarily an urban initiative based on our cost assessment (51 percent of EU households live in urban areas). On average across scenarios, 25 percent of total investment is required to upgrade and deploy urban infrastructure (51 percent of EU households), 34 percent is required for suburban (30 percent of households) and 41 percent for rural infrastructure (19 percent of households).

Looking at results by country, Europe consists of a heterogeneous sample of leading broadband infrastructure countries such as Belgium, Latvia and Slovenia on the one hand and countries with less advanced infrastructures such as Cyprus, Greece and Poland on the other. The countries requiring most of the total investment are Germany (between EUR 14 and 43 billion), France (between EUR 9 and 31 billion) and the UK (between EUR 11 and 26 billion). It turns out that the five biggest countries in terms of population (France, Germany, Italy, Spain and the United Kingdom) require between 63 percent and 72 percent of the total cost, more than their share in total EU population (62 percent). Furthermore, while the EU-15 accounts for between 80 percent and 84 percent of total cost (in line with its share in total EU population), it is below 40 percent of the total cost of reaching Target 1 across scenarios except for the maximum scenario. Reaching Targets 2 and 3 in the EU-15 would require 81-83 percent of the total cost. Thus, also apparent in coverage statistics, although EU-15 is more advanced in enabling basic broadband, it is in fact not much ahead of the new member states in NGN infrastructures. This is partly due to technological leapfrogging, that is, the new member states are not bound to legacy copper lines but have switched directly to deploying fibre.

A map illustrating the estimated total country costs per target can be found in Appendix 1.

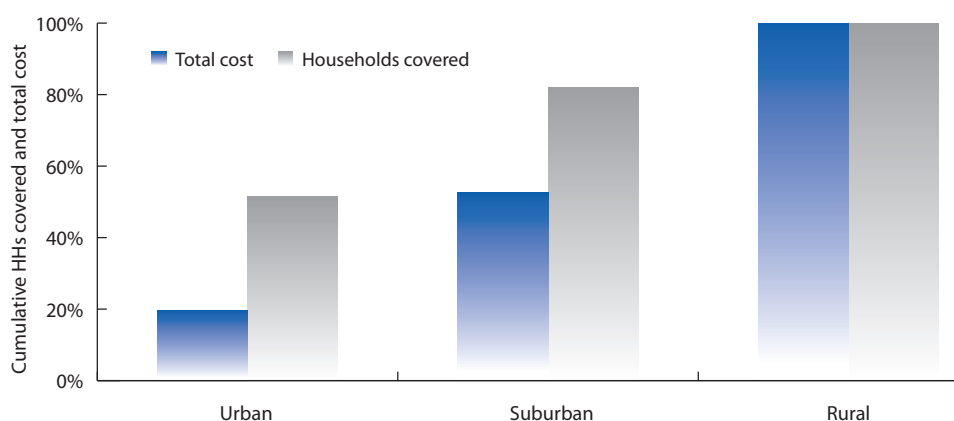
### **5.3 Implications of the cost assessment**

Overall, the results translate into a yearly investment need of between EUR 5 and EUR 22 billion, which is significant given, for instance, that in 2008 the total capital expenditure in the electronic communication sector in the EU amounted to EUR 47 billion. Therefore, and regardless of the interpretation of the DA targets and the underlying technologies, the high investment costs combined with long payback periods involved with these infrastructures and the uncertain cashflow streams related to them affect market-driven investments. Moreover, total investment in the telecommunications industry is declining in the EU, not only due to the macroeconomic climate but mainly because of the declining revenue outlook in the industry. What is more, investment is declining at an even faster pace than the revenues. The intensity of investment as measured by the ratio of capital expenditure to revenues is declining but is estimated to remain around 11 percent (down from a level of 14 percent in 2008 and 15 percent in 2007). This will increase the amount of public support needed for the DA targets to be met.

95 percent of the total estimated cost falls on achieving the targets regarding the higher access speeds (Targets 2 and 3) that require deployment of NGNs. Although mostly beneficial from an overall economic point of view (see Section 7 below), such investment needs create a great financial stretch for the

industry, in particular because a substantial part of the investment is expected to have low financial return. The results of this study suggest that rural areas account for over 40 percent of the total investment requirement, although they occupy less than 20 percent of all European households. In fact, the higher the quality requirements, the higher the share of cost falling on rural areas. Figure 9 illustrates the cost distribution of full EU-wide FTTH deployment (totalling EUR 208.6 billion), which is based on maximum scenario Target 2.<sup>3</sup> Accordingly, to connect 51 percent of the EU population (those living in urban areas), only 20 percent of the total cost is required. To cover all households in urban and suburban areas (81 percent of EU population) only some 50 percent of the cost is required, while the rural areas with less than 20 percent of the population require the remaining 50 percent of the total cost.

**Figure 9. Cumulative shares of total cost and households covered in full FTTH deployment scenario**



Note: "Urban" refers to areas with more than 500 inhabitants per km<sup>2</sup>, "Suburban" to areas with 100–500 inhabitants per km<sup>2</sup> and "Rural" to areas with less than 100 inhabitants per km<sup>2</sup>.

Although from the perspective of fulfilling the DA targets it is tempting to assume lower quality requirements, this would not provide a useful base for further development. For instance, it is not worthwhile to discuss theoretical or advertised speeds of technologies, as they do not reflect reality. It would be like building a motorway where the theoretical speed is given by the physical limits of the vehicle, but in reality traffic and speed limits imply a much lower actual speed. Also, as will be discussed further in Section 7, the benefits of NGNs increasingly derive from services relying not only on super-high download speeds, but also on similarly high upload speeds. Our "Maximum" scenario is the only one to cater to this important development. With these assumptions, and to simplify further analysis and reporting, the following sections focus on full EU-wide FTTH deployment – although the methodology could be applied to any other technology.

**...lax interpretations of quality requirements would not be useful.**

## 6. Assessing the financing gap in the deployment of NGNs

The key question in addressing the level of public intervention required to reach the DA targets is to assess the level of financing gap, in our case defined as the difference between the investment cost of full EU-wide FTTH deployment and the sum of funds likely to be provided by the private sector to finance that investment.

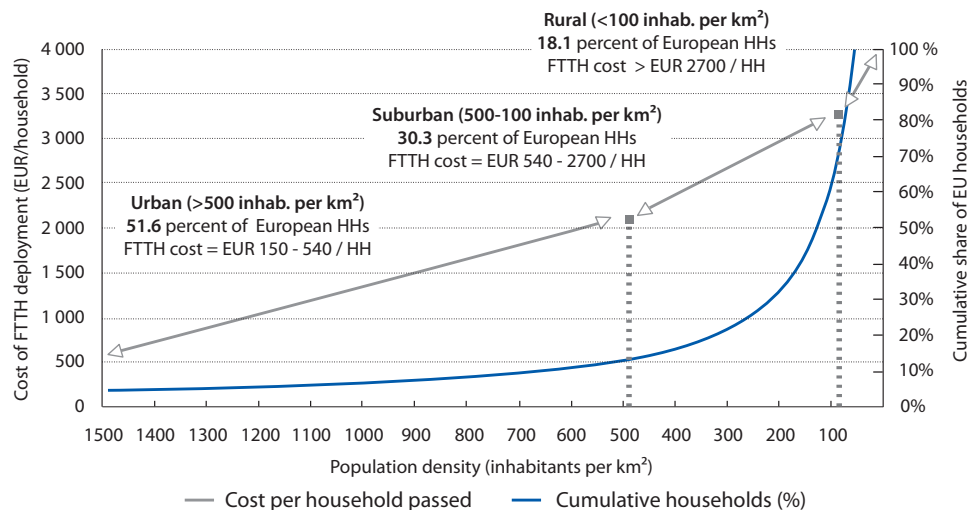
<sup>3</sup> In the maximum scenario, the requirement to meet Target 2 is to deploy infrastructure allowing 30 Mbps actual symmetric speed. Only FTTH technology is able to provide that.

**To assess the financing gap, NGN deployment costs are compared with the capex threshold (i.e. the maximum capital expenditure that can be funded by revenues).**

The methodology used to examine the financing gap consists in finding so-called capital expenditure (capex) thresholds for market operators to provide a business case for fibre deployment. The capex threshold is the maximum capital expenditure that can be funded by expected revenues, that is, the investment volume up to which FTTH deployment is financially viable. Finding the capex thresholds first requires developing a cost curve as a function of population density, which can be represented in a cumulative manner, going from high-density (i.e. low-cost) areas to low-density (high-cost) areas. This representation allows stating that, for instance, 40 percent of EU households live in areas where FTTH deployment costs less than EUR 500 per HH. Next, hypothetical business cases are built using multiple scenarios, variables, and sensitivities, from which the capex thresholds are derived. These capex thresholds can then be translated into population densities, and further to the share of total required cost based on the results of the cost study. The difference between the capex threshold and the total cost of deploying an EU-wide FTTH network gives an indication of the financing gap.

The reported costs for a household passed with fibre (FTTH) vary greatly with population density. The cost is of course dependent on several other variables such as availability of ducts, type of terrain and local labour costs. EIB experience and industry benchmarks were used to identify the cost distribution curve in different population density areas. The identified cost points were further connected by applying a relatively simple methodology<sup>4</sup> given limited data availability. By applying this approach, we arrive at cost levels between EUR 150 and EUR 540 per home passed in urban areas, between EUR 540 and EUR 2700 in suburban areas, and over EUR 2,700 in rural areas (Figure 10). For each home passed, there is a fixed-cost element irrespective of population density. It is estimated at EUR 150 per home passed and represents the lowest possible cost level.

**Figure 10. Cost of fibre deployment per household and population density in the EU**



From these cost estimates, it is now possible to derive the capex thresholds for market operators to invest in fixed infrastructure, assuming – as is typically done – a 10 percent discount rate (weighted average cost of capital – WACC) and a 10-year payback time. To obtain the capex threshold per home

<sup>4</sup> A benchmark value for deployment cost of EUR 112,500 per km<sup>2</sup> is derived based on various sources of industry benchmarks and EIB experience on costs per household covered in different areas with varying population density. This translates into an average cost per household passed at different population densities (assuming 2.4 inhabitants per household on average based on Eurostat). For the purpose of this analysis it is assumed that the household size is the same in different density areas. While this is a simplification, it gives a sufficient base for assessing the finance gap. Also, due to the fact that the deployment cost is dependent on a number of cost variables, with no data available for several of them, an accurate computation would be impossible to achieve anyway.

passed, a hypothetical business model is built for three different ownership scenarios: Single proprietary network deployment; single open-access network deployment; and single network co-build by three market operators (Table 1). The deployment of a proprietary network allows the service provider to collect relatively high average revenue per user (ARPU)<sup>5</sup> and to achieve a relatively high service uptake due to lack of competition. The deployment of an open-access network in turn allows wholesale offerings (i.e. leasing of the network capacity to other operators), which is, however, expected to slightly lower the uptake of direct retail service. The co-building scenario allows shared capex, but is likely to result in lower ARPU and uptake for the individual service provider due to increased competition. For each of the scenarios, a low and high variant is built based on service uptake.<sup>6</sup> The assumptions underlying the EBITDA margins (retail, wholesale and “co-build”) are based on industry benchmarks.<sup>7</sup>

**To push up the capex threshold, an operator may aim for wholesale revenues (opening the network to rivals) or for lower costs through collaborative roll-out and co-ownership.**

**Table 1. Scenarios and variables for assessing market thresholds for NGN deployment**

Type of deployment	Variables	Sensitivity variables	Capex threshold
Single proprietary network deployment	Retail ARPU EUR 50 per month and EBITDA 40 percent of revenues	High scenario uptake 40 percent and low scenario uptake 25 percent	EUR 648 / HH in high scenario and EUR 405 / HH in low scenario
Single open-access network deployment	Retail ARPU EUR 50 and wholesale ARPU EUR 15 per month; retail EBITDA 40 percent and wholesale 80 percent of revenues	High scenario retail uptake 30 percent and wholesale 20 percent, and low scenario retail uptake 20 percent and wholesale 10 percent.	EUR 681 / HH in high scenario and EUR 421 / HH in low scenario
Single network co-build by three operators	Retail ARPU EUR 40 per month and EBITDA 60 percent of the revenues	High scenario uptake 20 percent per service provider (i.e. 60 percent total) and low scenario uptake 10 percent per service provider	EUR 1,160 / HH in high scenario and EUR 584 / HH in low scenario

Notes: ARPU = average revenue per user; EBITDA = earnings before interest, tax, depreciation and amortization; HH = household. Certain factors which may shift market operators’ willingness to invest not included. For example, upsides not included in the model are market share protection for converged operators, and the fact that there is no upfront connection fee assumed. A downside not included is that all the models do not take into account areas with existing own or competing networks (ADSL2+ or cable).

With these assumptions and baseline variables, it seems that the capex threshold for deploying a commercially viable single proprietary network is in range between EUR 400 and EUR 650 per home passed, between EUR 420 and EUR 680 for a single open-access network deployment, and between EUR 580 and EUR 1,160 for single network co-build.

5 The ARPU of EUR 50 is based on Broadband Internet Access Cost (BIAC 2009) report on a dual-play offering (Internet +20 Mbps and TV). The EU-27 average for such service was EUR 52 in 2009. A dual-play offering is selected as the baseline here although a triple-play offering including fixed telephone service would provide a premium of EUR 10. On the other hand, some customers may opt for a single Internet service with an average cost of EUR 40.

6 It is also assumed that the implementation is in areas with no existing network for the deploying operator. If there was an existing DSL network, for instance, this would significantly degrade the capex threshold and hence, the willingness to invest, as revenue calculations would additionally have to take into account the loss of revenues from the existing DSL service. Especially for incumbent fixed-line operators with wide existing DSL networks, this is a key factor hindering their willingness to invest into FTTH infrastructures.

7 It is acknowledged that there is a positive correlation between the EBITDA margin and uptake of the service due to economies of scale. However, for the purposes of our assessment, average margins are used based on industry benchmarks in order to avoid making the assessment overly complex.

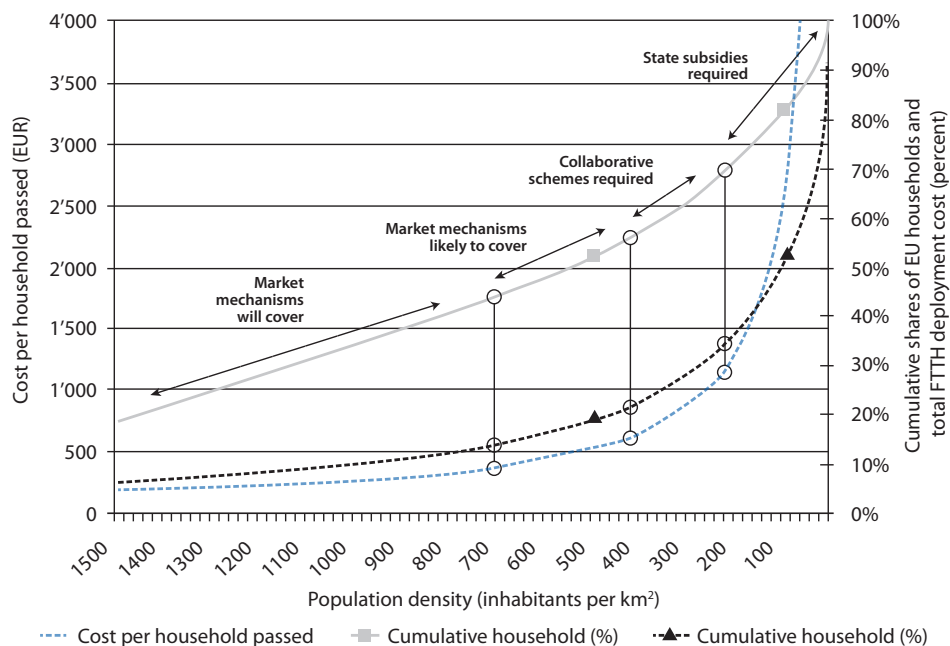


Figure 11 illustrates the capex thresholds with the unit cost curve combined with coverage of cumulative households. Based on the results, the following areas can be identified:

- Areas with full financial viability: Each deployment scenario is expected to yield positive returns for deployment cost less than EUR 405 per home passed. According to the cost curve, this corresponds to areas with more than 670 inhabitants per km<sup>2</sup>. Deployment up to this low capex threshold would cover 45 percent of the EU-27 population, while representing only some 15 percent of the total estimated cost of deploying an EU-wide FTTH network.
- Areas with high likelihood for financial viability: Network deployments of a single operator may enjoy financial viability up to a unit cost of EUR 680 per household passed. This would cover areas with population density of more than 400 inhabitants per km<sup>2</sup> and represent some 55 percent of the EU population. This still represents only 21 percent of the total investment need.
- Areas in which financial viability can be attained through collaborative deployment schemes: Through co-deployment schemes, financial viability can be achieved up to a unit cost of EUR 1,160 per HH passed, corresponding to a population density of more than 220 inhabitants per km<sup>2</sup>. This translates into an estimated 70 percent of the EU population, but only some 35 percent of the total cost.
- Areas in which state subsidies are required: In the remaining areas with population density below 220 inhabitants per km<sup>2</sup>, it seems that direct public financial support (e.g. grants) is required to make the FTTH deployment viable. As Figure 11 shows, 65 percent of the total cost is required to cover the “last” 30 percent of the EU 27 population (61.5 million households).

**While market mechanisms together with collaborative schemes would shoulder 35 percent of the cost, covering 70 percent of EU households...**

Figure 11. The estimated financing gap in FTTH deployments



While the financing gap assessment above is based on a bottom-up approach, it is also relevant to assess the top-down approach. Indeed, the market cap for investments in the FTTH deployments depends on how much the market can afford to invest. In this respect, the total telecommunications market revenues were EUR 341 billion in 2008, with total capital expenditure of EUR 47 billion, corresponding to an investment intensity of some 14 percent (capex/revenues). Of the total investment, 70 percent is for fixed line (EUR 33bn) and 30 percent for mobile (EUR 14bn), although especially for



converged operators this distinction is difficult to make. Furthermore, of the total investment in fixed line, only a limited share goes to new network deployment, while the majority goes to upgrading and maintenance of existing infrastructures, and also to data centres, buildings, capitalized R&D costs etc. It is estimated that roughly 20 percent to 30 percent of the total fixed line capex is directed to new network deployment, translating into a total amount of EUR 6.5 to EUR 10 billion. Over a 10-year horizon, based on the DA target for 2020, this would result in aggregate investment in new network infrastructures between EUR 65 billion and EUR 100 billion, which would correspond to 31-48 percent of the total estimated FTTH deployment cost and would translate into coverage of 67-80 percent. As a consequence, the top-down assessment is broadly consistent with the bottom-up analysis provided above.

However, due to market imperfections, these coverage figures are unlikely to be achieved through market mechanisms. Firstly, due to competition and the general aim of profit maximization, parallel deployments are likely to occur in the most profitable areas such as large cities and other densely populated areas. Secondly, currently 70 percent of fixed-line investment is done by incumbents. Incumbents with existing nation-wide xDSL connections are unlikely to deploy FTTH networks and to migrate customers to them, as the additional ARPU from having a super-fast broadband instead of fast broadband (xDSL based on copper) is currently limited.

Changing any of the underlying assumptions could change the results of the analysis significantly, because the identified capex thresholds and finance gaps are dependent on several variables and assumptions. Still, it provides an interesting illustration of the potential financing gap in reaching the DA targets regarding NGNs. In respect of using technologies (e.g. FTTB or FTTC) requiring lower capex per household covered, the variables throughout the assessment would change. For instance, while the capex is lower, the lower quality would definitely lead to lower ARPU and uptake rates due to lower added value and therefore willingness to pay. In fact, the key aspect behind the financing gap exercise is the added (perceived) value of NGNs and therefore the willingness to pay – further determining the ARPU and uptake rate which are the key variables in the financial viability assessment. The issue of added value of NGNs is further discussed in the following section.

Nevertheless, it is quite apparent that in reaching the DA targets especially with respect to NGN deployment, market mechanisms alone are unable to deliver the envisaged large coverage. Public support is required to reach the targets in full. However, the rationale for public support is contingent on the positive economic return of these networks, *i.e.* on a positive net benefit from society's perspective. The issue of economic returns to broadband and NGNs is discussed in the following section.

***...the remaining coverage requires public support, which should be carefully assessed against net social benefits from NGNs.***

## **7. Socio-economic benefits of broadband and NGNs**

There exists a vast literature on the socio-economic benefits of telecommunications, Internet and broadband. For instance, in 2010, in the context of the UK Government digital inclusion work, Tech4i2 assessed the existing literature on economic benefits of Internet and found a total of 365 studies and research papers on the area. 41 percent of the studies examine the impact in the context of the US, while only 17 percent focus on Europe. A similar exercise was conducted by World Summit on the Information Society (WSIS), which summarizes 186 studies on the economic impact of broadband infrastructure and services. The key socio-economic benefits of the Internet outlined by the existing research are: increased economic growth and productivity, increased employment, improved healthcare and education systems, a positive impact on the environment, improved social inclusion, improved safety, improvement of well-being, and so on. This section first discusses the impact of Internet and

broadband on economic growth and employment, followed by a discussion of the wider socio-economic benefits of basic Internet and broadband. In the final sub-section (7.3), the potential socio-economic benefits specific to super-fast broadband (NGN) are discussed.

### 7.1 Impact on economic growth and employment

Within the telecommunications domain, the main area on which the existing research has focused is the Internet's impact on employment and output, often stressing the Internet's positive effect on productivity growth and further on GDP growth. Stemming from the early study by Röller and Waverman (2001) who conclude that one third of growth in OECD countries between 1971 and 1990 can be attributed directly or indirectly to telecommunications, researchers have increasingly looked at identifying the growth effect of telecommunications, and later, of Internet and broadband in particular. Such studies account for 36 percent of all the studies identified by Tech4i2. This is due to the fact that these benefits are quantifiable, unlike the broader social benefits of the Internet.

A relatively unified consensus has evolved on the positive effect of broadband on economic growth and employment. Czernich *et al.* (2009), for instance, conclude that a 10 percentage point increase in broadband penetration raises annual per-capita growth by 0.9-1.5 percentage points. Similarly, Qiang and Rossotto (2009) find that a 10 percent increase in basic broadband penetration lifted GDP growth by an additional 1.12 percentage point in high-income countries. On productivity growth, LeCG find in their study that one more broadband line per 100 inhabitants (1 percent increase) in medium or high ICT countries increases productivity by 0.1 percent (LeCG 2009). Similarly, Friedrich *et al.* (2009) conclude that a 10 percent higher broadband penetration in a specific year is associated with a 1.5 percentage point greater labour productivity growth rate over the following five years. In sum, despite slight differences in the way the Internet's impact on productivity growth and GDP is measured and the variables used, prior research is relatively consistent in that every 10 percent increase in broadband penetration results in 0.9 to 1.5 percentage point higher GDP growth.

***Marginal returns to broadband are large and have increased over time as the usefulness of communication networks increases with the number of users.***

One interesting aspect of the telecommunications industry is that there exist increasing economic returns to scale and time. It is quite evident that in low-penetration countries, the lack of usage of broadband as an information and communications channel lowers the economic impact unless some critical mass is achieved. According to Koutroumpis (2009), the critical-mass effect can be achieved when 50 percent of the population in a given country has access to a broadband connection. As achieving the critical mass takes time – inevitably – time is an important factor in the analysis of economic benefits. Rausas *et al.* (2011), for instance, conclude that as markets mature, the contribution of the Internet to GDP growth increases: for example, in France the contribution is found to be 10 percent for the full observation period (1995-2009) but 18 percent in the later period (2004-2009). Across the range of mature countries they consider, the Internet contributed 21 percent to GDP growth, so for economies growing at 5 percent per annum, the impact of the Internet would be around 1 percent.<sup>8</sup>

Overall, Internet's and broadband's impact on GDP growth and productivity can be further broken down to different components, namely (i) employment generation, (ii) improvement in market efficiencies and consumer surplus, and (iii) improvement in productivity and operational efficiencies.

Firstly, in respect of employment generation, there have been arguments that the Internet has a negative or neutral impact on employment (*e.g.* Kenny and Kenny 2011). However, a detailed analysis

<sup>8</sup> While this study focuses on the contribution of the Internet, it seems reasonable to assume that this is closely related to broadband, which has been the key driver of the mass market take-up of Internet-delivered services in the last decade.

of France over the past 15 years shows that, although the Internet has destroyed half a million jobs, it has created 1.2 million new ones translating into 2.4 new jobs for every one destroyed (Rausas *et al.* 2011). Further Fornefeld *et al.* (2010) find that the impact of broadband on companies resulted in a net creation of 105,000 jobs in the EU-27 in 2006, and broadband-related net job creation is estimated at more than 2m jobs between 2006 and 2015. In the context of the UK, Liebenau *et al.* (2009) find that an additional GBP 5 billion investment in broadband networks would create, and retain, an estimated 280,500 jobs in the UK. On a more general level, Crandall *et al.* (2007) report that for every 1 percent increase in broadband penetration, employment is projected to increase by 0.2 to 0.3 percent. In a historical assessment, Qiang and Rossotto (2009) find that broadband added 10-14 percent to the growth rate in the number of jobs between 1998 and 2002.

**Studies on the GDP impact of broadband distinguish between employment generation; improving market efficiency and consumer surplus; and effects on productivity.**

Overall, the impact of broadband for employment is three-fold. For one thing, the deployment of broadband infrastructures directly creates employment, however often restricted to the short term. Secondly, once the infrastructure is deployed, direct employment is created in the operation of the network. Thirdly, telecommunications generate employment in adopting and supporting industries. Studies have found that for every job the industry itself creates, two others are created in support services catering to the industry, and one more is created through the taxes collected from the increased revenues. However, from an economic perspective, the counter-argument remains for some of the above studies that a net increase in sectoral employment does not necessarily result in aggregate employment or welfare gains as the jobs created may be lost elsewhere or drive up wages.

For another, the growth effect of broadband derives from improving market efficiencies and consumer surplus. Market efficiencies translate into improved communication between the seller and potential buyers. However, in some cases the improvement of market efficiencies may result in a negative impact on GDP for an individual country by shifting the trade balance. For instance, while for several countries with low-cost manufacturing capabilities such as India and China, the increase in exports is a key economic benefit of the Internet, for some developed countries such as France, the UK and Italy, the Internet has increased imports more than exports (Rausas *et al.* 2011). Broadband has also been found to have the positive impact of attracting FDI inflow to the country.

Consumer surplus derives from consumers' ability to save money by being able to compare prices and order products online irrespective of the country of origin of the seller. In fact, private consumption via Internet currently accounts for 1.8 percent of mature countries' total GDP (Rausas *et al.* 2011). To the extent that this only reflects redistribution of consumer expenditures, it does not boost economic growth, but there are economic benefits from broadband. A clear indication of consumer surplus in broadband is consumers' willingness to pay for upgrade from dial-up (see *e.g.* Savage and Waldman 2004). A study by Rosston *et al.* (2010) finds that the average US household would be willing to pay about USD 45 per month to move from "slow" to "fast" broadband, indicating that fast broadband access generates value for consumers. On average, the estimated surplus value per Internet user in developed nations is between EUR 13 and EUR 20 per user per month (Rausas *et al.* 2011). However, what facilitates growth is competition within the sector leading to lower consumer prices (see *e.g.* Greenstein and McDevitt 2011). Therefore, network deployments which increase competition are likely to result in consumer surplus and hence, carry a growth impact.

Further, as to improvements in productivity and operational efficiencies, several studies have outlined that Internet leads to operational efficiencies and therefore productivity gains through more efficient supply, rationalization and digitalization of operations, and use of Internet as an important and low-cost sales and marketing channel. A study estimates that in France, Germany and the UK, businesses adopting Internet business solutions had accumulated additional revenues of EUR 86.4 billion and achieved cost savings of EUR 9 billion already by 2001 (Varian *et al.* 2002). Grimes *et al.* (2009) study the

impact of slow and faster broadband access on firm productivity and find that firms with broadband connectivity had ten percent higher labour productivity than similar firms without broadband connectivity. Rausas *et al.* (2009) find that SMEs using Web technologies extensively are growing more quickly and are exporting more widely. There also exists a positive correlation between broadband penetration and innovativeness at the country level.<sup>9</sup>

## 7.2 Wider social benefits of broadband

**Social benefits from the Internet include improved education and healthcare and positive effects on the environment.**

In addition to the widely reported economic benefits, it is generally acknowledged that telecommunications and the Internet create a wide range of social benefits such as improved education and healthcare systems, better social inclusion, enhanced regional development, positive effects on the environment, improved safety, and a positive contribution to democracy and freedom of speech. Some of the key socio-economic benefits are discussed in more detail below.

In respect of the environment, although the telecommunications sector accounts for approximately 2 percent of global CO<sub>2</sub> emissions, it accounts for close to 4 percent of global GDP. Furthermore, it is widely argued that broadband connections reduce the requirement to travel, both for business and in private, and therefore result in significant savings in CO<sub>2</sub> emissions. The positive impact of telecommunications and ICT in general is the highest in the adopting industries. For instance, the SMART 2020 report finds that Information and Communications Technologies (ICT) could deliver 7.8 Gt of CO<sub>2</sub> equivalents of emission savings in 2020, or 15 percent of global emissions in 2020, through applying smart solutions in automotive industries, logistics, construction and electricity. The application of intelligent ICT systems in motors, electricity grids, transport systems and buildings is expected to provide significant positive impacts on the environment. However, are these benefits related to broadband or ICT in general? Some argue (*e.g.* Kenny and Kenny 2011) that in fact the data transferred in solutions such as the smart electricity grids are so small, that they do not really require broadband connectivity – while others argue that smart grids are a benefit from super-fast networks (Ezell *et al.* 2009). Nevertheless, it is safe to assume that broadband enables several ICT based solutions applied in various industries, as well as enabling travel reduction, with high positive impacts on the environment.

Secondly, there has been a wide research on the impact of broadband in education and healthcare. In the area of healthcare, for instance, broadband networks enable distant monitoring and treatment, particularly of elderly people or people with chronic illnesses, leading to economic benefits through reduction in hospital admissions, emergency room visits and related transportation (see *e.g.* Enck and Reynolds 2009; CTC Report 2009). In the area of education, broadband enables, for instance, e-learning especially in rural and more remote areas, thereby also contributing to regional development. Virtual classrooms are set up where the distance between the pupils and the teacher has become irrelevant. Broadband access speeds are required to transfer video, sound and data between the student and the teacher.

While the benefits deriving from the environment, healthcare and education can be quantified to a certain extent, other social benefits of broadband such as the contribution to democracy and freedom of speech, increased social inclusion remain qualitative by nature. While these benefits are apparent also in developed nations, the key benefits in this respect occur in emerging economies.

<sup>9</sup> Among the EU-27 countries, a positive correlation exists between broadband penetration in 2009 and the related Innovativeness score of the country taken from European Innovation Scoreboard 2009 (InnoMetrics). The correlation coefficient is 0.40.

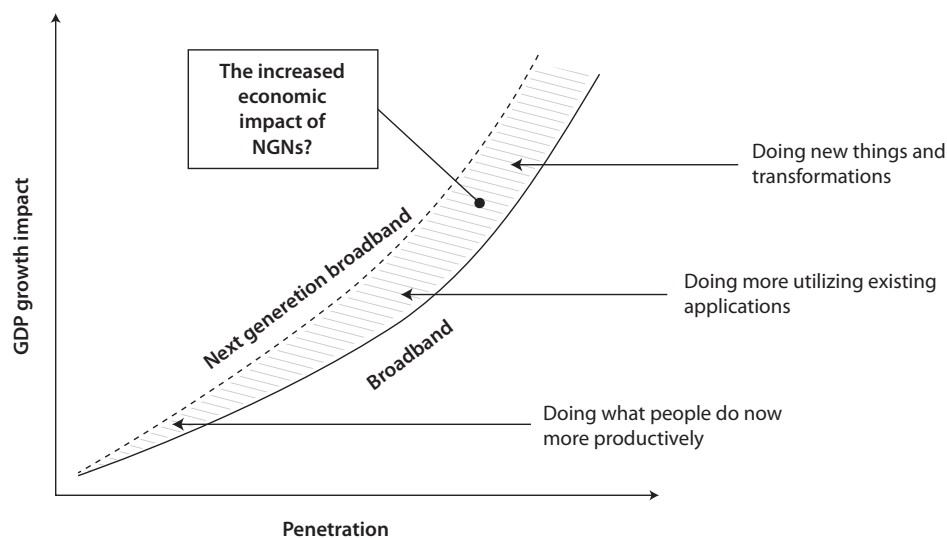
### 7.3 Socio-economic benefits of NGNs

In spite of the extensive research on the socio-economic impact of Internet and broadband, there is practically no existing research on the socio-economic benefits of super-fast broadband. Comparative assessments have been made in the past to address the added benefits from transferring from dial-up connections to broadband connectivity. However, the transition from basic broadband to next generation networks is more complex as it involves deploying entirely new network infrastructures, implying a great cost to the industry. From a policy perspective, when it comes to public support for the deployment of these networks, the key question is: Do the benefits of NGNs outweigh the cost of deploying these networks? And related to this, Kenny and Kenny (2011) rightly ask: “Is it really worth a subsidy?”

The complexity of this issue stems from the fact that, while it is relatively simple to address the impact of the Internet using no connectivity as a business-as-usual scenario, the assessment of NGNs needs to be done in comparison to existing basic broadband, which is available for almost the entire population of the EU. However, some initial attempts have been made to address this problem. In their assessment for the Broadband Stakeholder Group, Plum Consulting (2008) developed a framework for evaluating the value of next generation broadband. They consider three categories of benefits deriving from the replacement of existing copper networks with super high-speed fibre networks: (i) doing what people do now more productively (the value of time savings); (ii) doing more utilizing existing applications; and (iii) doing new things and transformations (Figure 12).

*The benefits of super-fast over basic broadband concern time savings; ‘doing more utilizing existing applications’; and unknown future transformations.*

Figure 12. The socio-economic benefits of NGNs



First, in respect of “doing what people do now more productively”, one approach would be to assess the time savings that can be achieved through NGNs. For the economic assessment of building new roads, for instance, time saving is one of the most commonly used variables in calculating the economic return. Similarly, it can be argued, in respect of broadband networks, that faster connections lead to time savings that can be monetized as an economic benefit. For instance, if we consider that out of the total EU-27 population of 492 million, 67 percent are of working age and the average value of time is EUR 10 per hour<sup>10</sup>, only a one-minute daily saving per person resulting from the increased speed of the

<sup>10</sup> Average based on different values of time for business, commuting / private time and leisure / holiday provided by van Essen *et al.* (2004). Although the valuations are built for assessing transport projects, the value of time should not differ.

network would result in an economic value of time savings of around EUR 20 billion a year. For example, one minute of time saved corresponds to the downloading of 40 Mbytes a day<sup>11</sup> with a 100 Mbps fibre connection, as compared to a 5 Mbps (ADSL) connection (currently the average). Although this calculation is illustrative only and neglects obvious counterarguments (*e.g.* increased speeds actually increase the frequency of use of the service), it underscores the economic potential of super-fast networks.

The value of time can also be assessed from a corporate perspective, whereby the basic hypothesis would claim that faster networks lead to operational efficiency gains. As a practical example, hospitals are increasingly moving towards IP standards whereby x-rays, medical samples *etc.* can be stored and shared in a digital format. This, however, requires significant download and upload access speeds as single images can be the size of two DVDs at the moment (8-9 Gbytes), and with the increase in accuracy of imaging and displays, the size is bound to increase. Using a VDSL2 connection, uploading a single image would load the network for over 2 hours, and accessing it would also require 25 minutes. With a symmetric 100 Mbps connection, both uploading and downloading would take an estimated 12 minutes, and with a 1 Gbps connection these actions altogether would require just over a minute. Therefore, common sense suggests that with faster connections, doing the same thing consumes less time and, hence, a certain level of economic benefits can be derived from NGNs.<sup>12</sup>

**A number of services (e.g. videoconferencing and e-health) are only available via NGNs as they require high upload as well as high download speeds.**

Second, as far as “doing more utilizing existing applications” is concerned, the key focus lies in assessing which applications are only available through NGNs. In the case of NGNs and fibre-based networks, it is generally argued that these networks will allow the roll-out of high-value applications which cannot be delivered in any other way, suggesting that additional bandwidth carries considerable returns. Several studies have emphasized a number of benefits to electricity, health, education, transportation and other public services from fibre networks (*e.g.* Enck and Reynolds 2009; Ecobilan 2008; Ezell *et al.* 2009; Ovum 2009). However, Kenny and Kenny (2011) argue that there are in fact only few applications that rely on super-fast broadband connections, and the majority of the applications that generate economic value added can be provisioned through existing infrastructures. This calls for further service-based assessment of the problem.

As can be seen from Figure 13, the services such as browsing and social networking are easily accessible with basic broadband connections. Advanced TV services require very high speed download connectivity. The services which need faster speeds and eventually next generation fibre infrastructures include multi-location collaboration (videoconferencing), cloud computing services and specific industry-specific applications (*e.g.* e-health) – all involving two-way traffic and therefore imposing high requirements both on upload and download speeds.

However, the question is: Is there any economic value-added from these services? Cloud computing is one widely cited example of services enabled by NGNs with high returns to the economy. In 2005, there were about 20 million SMEs in the EU-27 area creating an annual value-added of EUR 3,090 billion (source: Eurostat). A typical SME, according to Gartner estimates, spends around 5-7 percent of its revenues on IT, of which an estimated 50 percent is targeted to IT infrastructure maintenance. This translates into an annual SME IT spending of EUR 154 to 216 billion, with EUR 77-108 billion devoted to IT infrastructure maintenance. With cloud computing cutting spending on IT infrastructure maintenance

11 The 40 Mbps is a very conservative assumption as a recent study by Sandvine (2011) reported that the median usage of a fixed-line user is around 500 Mbytes a day. Although some traffic is inactive – *i.e.* does not entail sitting and actively working on the computer – the majority of the traffic is still generated by Web browsing and real-time communication and entertainment.

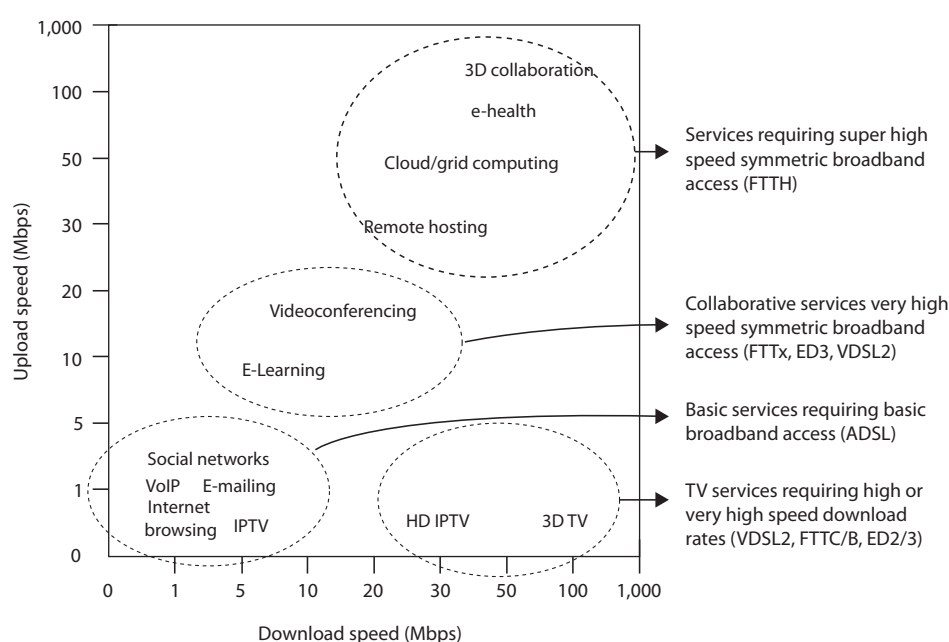
12 Grimes *et al.* (2009) find no difference in productivity between firms connected to ADSL versus firms connected to (usually faster) cable. However, the specific cable connections they looked at in their study do not allow much higher access speeds than ADSL, casting a shadow on their results.



by 30 percent according to conservative estimates, full adoption of cloud solutions by all European SMEs would lead to productivity gains of some EUR 23-32 billion per year, equivalent to 0.7-1.0 percent of value-added. Although it is unrealistic to expect full adoption of the service, this simple example provides an interesting illustration of the potential productivity gains from NGNs – that is, full adoption of a single application (cloud computing) only within SMEs would generate economic gains over the next 10 years outweighing the cost of deploying nation-wide FTTH network in the EU. Further benefits are likely to derive from large corporations as well. For instance, OECD (2009) calculates that cost savings in the range of 0.5-1.5 percent just in the four sectors electricity, education, transport and health – industries typically consisting of large corporations – would justify building a national FTTH network in the EU. However, it needs to be acknowledged that the majority of the large corporations are already connected to fibre networks, and therefore the additional productivity potential indeed lies in SMEs.

**Further fibre deployment would provide substantial benefits to small and medium-sized enterprises.**

**Figure 13. Speed requirements of different applications**



Notes: The figure illustrates the upload and download speeds required for different services (loosely based on El-Darwiche *et al.* 2009). How the services are defined has a great impact on the required speeds.

Finally, regarding “doing new things and transformations”, the potential economic benefits are difficult to assess due to the obvious lack of knowledge of such applications. Nonetheless, it is argued that the ever increasing consumer demand for sufficient bandwidth to support new applications and services creates the context for change in building NGNs (*e.g.* El-Darwiche *et al.* 2009). However, certain trends can be foreseen which create different requirements for these networks. Firstly, increasing advancements in imaging technologies (*e.g.* electronic microscopes, cameras *etc.*) across industries increases the need for networks which enable the transfer of large amounts of data in a short period. Secondly, the growing popularity of remote hosting, multi-location collaboration and cloud computing applications emphasizes the importance of two-way traffic, and therefore the need of network infrastructures capable of providing sufficient upload speeds.

The environment-related economic benefits from higher access speed networks derive from the services they enable. For instance, a recent study indicates that, along with the other cost savings, SMEs can decrease IT-related carbon emissions by 80 to 90 percent by adopting cloud services (Salesforce 2011). Another recent study (Ecobilan 2008) finds that fibre-enabled reductions in travel thanks to

tele-working and telemedicine only would result in emission reductions of 330 kg of CO<sub>2</sub> equivalent per user over 15 years. Accordingly, a 1-percent increase in FTTx use in the EU would result in CO<sub>2</sub> savings of over 100 ktons per year.

Overall, GSM Association (2009) estimates that advances in mobile broadband alone would add 0.5-1.0 percent to GDP in the in EU annually to 2015, entailing a cumulative increase by EUR 340-750 billion in the level of EU GDP from 2010 to 2015 – well above the estimated amount required for reaching the DA targets in any scenario. Fibre-based networks are likely to have a greater impact due to the higher quality of service, although lacking the value of mobility. Nevertheless, it needs to be noted that the economic benefits quoted by a number of earlier studies remain limited to current applications and solutions – and the applications are still limited due to a lack of fibre infrastructures. Value-adding services will be developed once the infrastructure is in place to enable them, not the other way around. In fact, Rosston *et al.* (2010) find that the average household is willing to pay about USD 45 per month to move from “slow” to “fast” broadband, but it is willing to pay only USD 3 per month to move from “fast” to “very fast” speeds. This suggests that consumers at least do not see the additional value of having super-fast broadband at the moment. However, the willingness to pay tends to grow as customers get used to better-quality services. Therefore, the economic benefits described are just the baseline, with likely upsides deriving from future applications and service development.

## 8. Public support mechanisms for NGNs

**The EU has adopted guidelines on how to apply state aid rules to the public funding of broadband networks in general and NGN deployment in particular.**

Policy makers in Europe have, in light of the Digital Agenda, initiated a discussion on how governments and the public sector should support the deployment of next generation networks<sup>13</sup> – basing the need of such networks on high economic benefits. The European Commission has adopted guidelines on the application of EC Treaty state aid rules to the public funding of broadband networks. These guidelines aim to provide a clear and predictable framework for stakeholders and will help the EU member states to accelerate and extend broadband deployment. Separate guidelines were recently developed with respect to state aid rules regarding NGN deployments (European Commission 2010b). Furthermore, it is stated in the Europe 2020 Strategy that the Commission is committed to providing a legal framework that stimulates investment in an open and competitive high-speed Internet infrastructure, and overall, to promote Internet access and take-up by all European citizens. Member states are expected to further polish their legal frameworks for coordinating public works to reduce the cost of network roll-out, and to draw up operational strategies including the provision of basic broadband and NGNs (including targets for public funding in areas not fully served by private investment) to reach the targets set in the DA.

There is a large literature on the role of the public sector in supporting broadband deployments (Table 2), see *e.g.* Friedrich *et al.* 2009; Nucciarelli *et al.* 2010. According to Friedrich *et al.* (2009), the level of government involvement can vary from being an observer (*e.g.* US and Germany), to being a facilitator (Sweden and Norway) or even a driver (Japan and South Korea). In addition to setting regulatory parameters for NGN deployment, government intervention can further take place through direct subsidization or co-development initiatives (also referred to as public-private partnerships or PPPs).

One of the key regulatory concerns relate to principles of access – not only to cables but also to the ducts and buildings. Gryseels and Begonha (2010), for instance, estimate that 40 to 50 percent of the fibre deployment business case can depend on the appropriate regulatory regime. However, the

<sup>13</sup> Within the European Commission, the discussion on financing broadband and NGNs followed directly after the introduction of the Digital Agenda (European Commission 2010a).



regulatory setting is multifaceted due to various technological and commercial aspects. Although right regulatory measures could prevent parallel and redundant network deployments by supporting network sharing, wrongly set tariff and/or access principles might limit competition. Still, by setting appropriate regulatory parameters, countries could ensure maximum coverage for any given level of market-driven investment while ensuring a competitive market environment.

Nevertheless, while appropriate and effective regulation is the key foundation enabling investment into NGNs, it does not directly attract investment. Regulation can lower the risk of deployment for the private sector while ensuring sufficient competition. Measures to oblige operators to roll out NGNs, similar to basic broadband through universal service obligations (USO) in some countries, are unlikely due to the large financing need and are in fact only efficient to reach the “last corners”.

The simplest model of government intervention is direct subsidization – *i.e.* state aid. This model involves a private sector operator receiving some level of public funding (often a grant) to assist in its deployment of a new network offering open wholesale access. The operator retains full ownership of the network (a valuable long-term asset for the operator) and the public sector is not involved in running the network.

As a variant to direct subsidization, government may subsidize by bringing down the cost of finance and by providing access to long-term finance. For instance, if in the financing-gap assessment discussed in Section 6, a WACC of 5 percent was used instead of 10 percent, the capex thresholds for market-driven investments would increase by 20 percent. Similarly, it may be difficult for market operators to find long-term credit exceeding 10 years. Therefore, enabling such finance would bring down the cost and risk of deployment.

***As a variant to direct subsidization, the government may bring down the cost of finance and provide access to long-term finance.***

Other methods of direct subsidization relate to direct deployment grants, bringing down the capex itself and therefore significantly improving the business case for private operators. However, since the economic benefits of NGNs derive from the uptake and use of services and not from coverage, the question arises whether to subsidize the uptake rather than the deployment *per se*. This can be done either by subsidizing (securing) a certain level of uptake to make the business case viable, or by directly stimulating demand for the network, be it by direct use in the public sector or by subsidizing consumer uptake of NGNs (see *e.g.* Friedrich *et al.* 2009 for illustrative examples). However, the key problem with direct subsidization is the availability of public funds and the fact that the private sector still needs to initiate, design and sometimes even implement these deployment projects even before any agreement on possible subsidies. Governments can also apply tax instruments (*e.g.* exemptions) that can be applied to support NGN deployments, which may significantly improve the financial viability of the deployment.

In respect of co-development (PPPs), different models vary from public outsourcing to joint ventures and fully public DBO (design, build, operate). In public outsourcing, a public-sector body outsources network build and operation to the private sector organisation under a long-term agreement, while retaining the ownership of the network. A joint venture is any agreement whereby ownership of the network is split between the public and private sector. Construction and operational functions are likely to be undertaken by a private sector organisation. In public DBO, all aspects of network deployment and operation are managed by the public sector. Although these three models are persistent, the level of public sector risk and involvement may significantly differ even within the different types of co-development projects. Although in all co-development models, the public sector can add financial stability and risk sharing ability to projects, public-sector involvement also adds a layer of bureaucracy to the deployment and bears the potential for conflicts of interest.

**Table 2. Advantages and disadvantages of different modes of public intervention**

	Regulatory setting	Financial support	Co-development
Advantages	Does not impose any financial burden on the public sector  Can lower the risk of deployment for the private sector while ensuring sufficient competition	Can lead to faster deployments  More suitable for funding widespread deployments as the public funding can be given to an established commercial operator to deploy and operate the network	Combines public-sector financial stability with private expertise  Allows different business models  Public sector retains a certain level of control and can ensure that socio-economic objectives are met
Disadvantages	A tool to remove barriers to investment, yet alone not sufficient to attract private investment to NGN	Private sector still needs to initiate projects  Limited ability to ensure that socio-economic objectives are met	Added bureaucracy to deployment and potential conflicts of interest

**Public funding to the industry appears to work for large-scale roll-outs, but setting the appropriate subsidy level is a challenge.**

Overall, the historical evidence from Japan and Korea, for instance, shows that a solution delivering funding to the industry appears to work for large-scale roll-outs (see *e.g.* Gryseels and Begonha 2010). The most problematic issue to assess is the level of public sector involvement, which is closely related to the commercial viability of the roll-out. While the problem of direct deployment grants lies in assessing their appropriate levels, also to avoid subsidization of competitive areas, the difficulty of PPP models seems to lie in the added layer of bureaucracy affecting the speed of deployment. One thing is sure, however: there is no one model that fits all. Rather, the appropriate policy mix depends on a number of factors including the characteristics of the area, the available technologies, and demand factors.

## 9. Summary and discussion

The aim of this paper has been to investigate the cost, financing gap, added economic value, and finance mechanisms of the potential deployment of NGNs in Europe. The paper builds on the specific broadband targets set forward in the Digital Agenda for Europe initiative by the European Commission which, although being fairly open to different interpretations, provides a sufficient understanding of the broadband development objectives in Europe for the coming years. The paper has taken a specific look at the Commission's targets to deploy super-fast broadband infrastructures in Europe, namely fibre-based next generation networks.

In Europe the use and availability of broadband technologies allowing super-fast broadband access is still lagging behind other digitally developed nations. FTTH coverage for instance is less than 10 percent of the European households. The average download speed of a broadband connection in Europe is 5 Mbps, and only 30 percent of the total broadband subscriptions are over 5 Mbps. This imposes significant need for development of broadband infrastructures, if the targets of 30 Mbps and 100 Mbps connectivity set in the Digital Agenda are to be met. The cost assessment provided in the article shows that overall an investment of between EUR 73 and EUR 221 billion would be required over the next 10 years in order to fulfil all the DA broadband targets, over 75 percent of which would be required for reaching Targets 2 and 3, *i.e.* those specifically referring to high access speeds. The wide range in the cost estimate is due to a vague description of the targets, leading to several possible interpretations, with each of them leading to a different set of technological options. In further analysis, this paper has interpreted the targets as meaning actual (as opposed to theoretical or advertised) speeds as this is what matters in assessing the real economic impact.

Overall, it has been estimated that to deploy a full EU-wide FTTH network, an investment of EUR 209 billion would be required. 50 percent of this cost would be required to cover 80 percent of the households located in urban and suburban areas in Europe, while the other 50 percent of the cost would be required to cover the remaining 20 percent of households located in rural areas. This raises two policy issues. For one thing, market-driven deployment alone is likely to be geographically unbalanced, favouring urban areas. What is more, total available private finance will not suffice to meet the targets of the Digital Agenda – a financing gap remains. It was estimated that market driven investments could cover up to 70 percent of the European population with FTTH networks, corresponding to 35 percent of the total investment requirement, through deployment of proprietary networks or with private-sector, collaborative deployment schemes. This coverage is, however, limited due to market imperfections. A sanity check of this bottom-up approach was done by examining the market's affordability to invest, which showed that the market cap for investments into FTTH infrastructures in fact lies at a level of EUR 10 billion per year, which over a 10-year horizon would correspond to less than 50 percent of the total investment requirement. Accordingly, public intervention would be called for to reach the DA targets.

***Deploying a full EU-wide FTTH network would require investing EUR 209bn – half of it to reach the 20 percent of households living in rural areas.***

However, there need to be economic benefits to society from these super-fast broadband networks to justify government intervention. There exists a wide literature on the socio-economic benefits of telecommunications, Internet and further broadband, emphasizing the positive impacts on GDP growth and productivity, education and healthcare, energy, social inclusion and so on. However, there have been only few attempts to assess the return on bandwidth, that is, what are the additional benefits of upgrading from basic broadband to super-fast broadband. The economic argument of NGNs lies in the fact that it enables (i) doing what people do now more productively (the value of time savings); (ii) doing more utilizing existing applications; and (iii) doing new things and transformations. Regarding point one, it has been calculated as an example that an average time saving of only 1 minute per working age inhabitant every day would lead to economic benefits from time savings equal to the cost of full fibre deployment. On point two, it has been calculated that full adoption of cloud services enabled by NGNs only within the SME sector would lead to productivity gains beyond the cost of deployment. The economic benefits of point three cannot be assessed due to the fact that these services are still non-existent.

Therefore, it seems there is high potential for economic benefits, which would in principle justify public sector intervention. In addition to setting regulatory parameters in such a way as to support market-driven investment, public intervention could be done through direct subsidization of capex of service uptake, or through various collaborative development schemes whereby the public sector would be involved, most often together with private parties, in designing, building and/or operating the network. There is no one model that fits all, and public intervention requires careful assessment of the environment. However, one needs to keep in mind when designing models for public intervention that there is a general misinterpretation when it is claimed that network deployments will lead to economic benefits, where in fact it is the uptake and use of the service. This is particularly true in the context of the planned NGN deployments where consumers still fail to see the additional value of super-fast broadband compared to fast broadband.

Finally, the following outcomes from the analysis in this paper are of interest for policy makers. First, while most people refer to broadband speeds as download speeds, upload speeds are in fact becoming increasingly important as the key services providing economic value-added enabled by NGNs require two-way symmetric access (e.g. cloud computing, multi-location collaboration etc.). In fact, upstream traffic already accounts for over 20 percent of the total traffic of an average fixed broadband user (Sandvine 2011), and this share is constantly increasing.

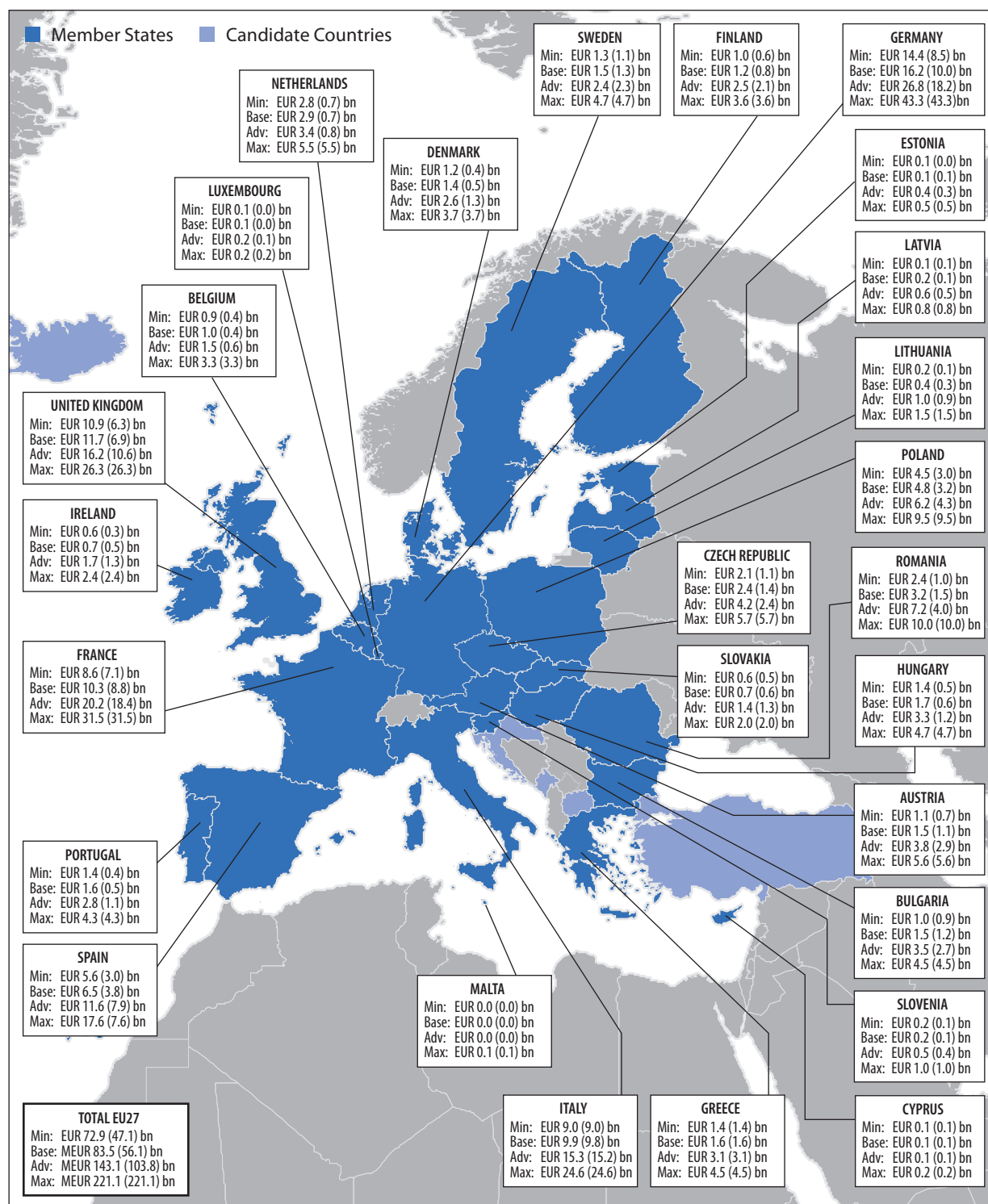
Second, while the uptake of NGNs unlocks certain economic benefits, it is the services they enable that provide the additional benefits. Therefore, new applications and service development should not be overlooked. It is reasonable to argue that there are increasing economic returns to bandwidth, yet decreasing returns to scale. This means that, although a 100 Mbps connection provides added economic value over a 2 Mbps connection, the 2 Mbps connection carries a significantly higher economic return per bit than a 100 Mbps connection. However, this nonlinearity is likely to be slightly corrected as new bandwidth-hungry applications are introduced requiring super-fast connection.

**Concentrating government support on rural areas would also help to meet digital-inclusion and regional-convergence targets.**

Third, from the perspective of digital inclusion and regional development it is imperative that the public sector support fibre deployment in rural areas, although the DA implicitly limits its 100 Mbps targets to urban areas. Therefore, fibre deployments focusing only on urban and suburban areas would lead to greater imbalance in digital inclusion, have a negative effect on regional development, and lead to negative congestion externalities by fostering agglomeration of economic activity in the better-connected urban and suburban areas.

Finally, in fibre deployment, increasing cross-industrial cooperation is called for. Recent studies (*e.g.* Kenny and Kenny 2011) suggest that installing fibre during road construction adds only about one percent to total construction cost. Given that an estimated 70 to 80 percent of the cost of fibre deployments relate to civil works, *i.e.* digging the ducts where fibre is laid, there are a lot of synergies to be attained from cooperation with industries in charge of roads, electricity, and water and sanitation.

## Annex 1. Total costs by country in all scenarios



Notes: Cost figures presented without brackets describe the total cost excluding cable in the calculation while figures in brackets represent total cost if the existing cable infrastructure is fully considered.  
The four scenarios (Minimum, Base, Advanced, Maximum) refer to different levels of quality in fulfilling the Digital Agenda targets (see Section 5.1).

## References

- Akamai (2011). *The State of Internet*, (4:1), 1<sup>st</sup> quarter, Akamai Technologies.
- Crandall, R., Lehr, W. and Litan, R. (2007). "The Effects of Broadband Deployment on Output and Employment: a Cross-Sectional Analysis of US Data". Brookings Issues in Economic Policy No. 6.
- Columbia Telecommunications Corporation (CTC) (2009). "Benefits beyond the balance sheet: quantifying the business case for fibre-to-the-premises in Seattle". Columbia Telecommunications Corporation (September), Kensington, MD, USA.
- Czernich, N., Falck, O., Kretschmer, T. and Woessmann, L. (2009). "Broadband Infrastructure and Economic Growth". CESifo Working Paper No. 2861.
- Ecobilan (2008). "Developing a generic approach for FTTH solutions using LCA methodology". Report prepared for the FTTH Council, February 2008.
- El-Darwiche, B., Weichsel, P., Trimmel, D. and Smayra, C. (2009). "The Era of Next-Generation Access: Building Networks to Meet New Demand". Booz & Company.
- Enck, J. and Reynolds, T. (2009). "Network Developments in Support of Innovation and User Needs". DSTI/ICCP/CISP(2009)2/FINAL, OECD, Paris.
- Etro, F. (2009). "The Economic Impact of Cloud Computing on Business Creation, Employment and Output in Europe: An application of the Endogenous Market Structures Approach to a GPT innovation". *Review of Business and Economics*, (2:2), pp. 179-209.
- European Commission (2010a). "European Broadband: Investing in digitally driven growth". COM(2010) 472
- European Commission (2010b). "Commission recommendation on regulated access to Next Generation Access Networks (NGA)". COM(2010) 6223 final
- Ezell, S., Atkinson, R., Castro, D. and Ou, G. (2009). "The Need for Speed: The Importance of Next-Generation Broadband Networks". Information Technology and Innovation Foundation, Washington, D.C., USA.
- Fornefeld, M., Delauney G. and Elixmann D. (2010). "The Impact of Broadband on Growth and Productivity". MICUS Management Consulting GmbH.
- Friedrich, R., Sabbagh, K., El-Darwiche, B. and Singh, M. (2009). *Digital Highways: The Role of Government in 21st-Century Infrastructure*. Booz & Co, New York, NY, USA.
- Greenstein, S. and McDevitt, R. (2011). "The Broadband Bonus: Estimating Broadband Internet's economic value". *Telecommunications Policy*, (35:7), pp. 617-632.
- Grimes, A., Ren, C, and Stevens, P. (2009). "The need for speed: impacts of internet connectivity on firm productivity". Motu Economic and Public Policy Research Paper 09-15, Wellington, New Zealand.
- Gryseels, M. and Begonha, D. (2010). "Fiber: The future of fixed in Europe". Paper presented at the FTTH Council Europe Conference in Lisbon, 25th February 2010.
- GSM Association (2009). "The European Mobile Manifesto – How mobile will help achieve key European Union objectives". October 2009.
- Kenny, R. and Kenny, C. (2011). "Superfast Broadband: Is It Really Worth a Subsidy?" Communications Chambers, February 2011 (2<sup>nd</sup> edition).
- Koutroumpis, P. (2008). "The economic impact of broadband on growth: a simultaneous approach". *Telecommunications Policy*, (33:9), pp. 471-485.
- LeCG (2009). "Economic Impact of Broadband: an Empirical Study". LeCG Ltd., London, UK.

- Liebenau, J., Atkinson, R., Kärrberg, P., Castro, D. and Ezell S. (2009). "The UK's Digital Road to Recovery". LSE Enterprise & ITIF.
- Nucciarelli, A., Sadowski, B. and Achard, P. (2010). "Emerging models for public-private interplay for European broadband access: Evidence from Italy and the Netherlands". *Telecommunications Policy*, (34:9), pp. 513-527.
- OECD (2009). "Network Developments in Support of Innovation and User Needs". Working Party on Communication Infrastructures and Service Policy, OECD, Paris (DSTI/ICCP/CISP(2009)2/FINAL).
- OECD (2011). "The Economic Impact of Internet Technologies". Working Party on the Information Economy.
- Ovum (2009). "Fibre: The Socio-Economic Benefits". Ovum, London.
- Plum Consulting (2008). "A Framework for Evaluating the Value of Next Generation Broadband". Broadband Stakeholder Group, London, June.
- Qiang, C.Z-W. and Rossotto, C.M. (2009). "Economic Impacts of Broadband Information and Communications for Development 2009: Extending Reach and Increasing Impact". The World Bank.
- Rausas, M.P., Manyika, J., Hazan, E., Bughin, J., Chui, M. and Said, R. (2011). "Internet matters: The Net's sweeping impact on growth, jobs, and prosperity". McKinsey Global Institute, May 2011.
- Röller, L.H. and Waverman, L. (2001). "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach". *American Economic Review*, (91:4), pp. 909-923.
- Rosston, G., Savage, S. and Waldman D. (2010). "Household Demand for Broadband Internet Service". Federal Communications Commission, Washington, D.C., USA.
- Salesforce (2011). "Salesforce.com and the Environment: Reducing Carbon Emissions in the Cloud".
- Sandvine (2011). "Global Internet Phenomena". Report Spring 2011, Sandvine Intelligent Broadband Networks, Ontario, Canada.
- Savage, S.J. and Waldman, D. (2004). "United States demand for Internet access". *Review of Network Economics*, (3:3), pp. 228-247.
- van Essen, H.P., Boon, B.H., den Boer, L.C., Faber, J., van den Bossche, M.A., Vervoort, K.T.H. and Rochez, C. (2004), "Marginal Costs of Infrastructure Use – Towards a Simplified Approach", CE Delft; results published in Vermeulen, J., Boon, B., van Essen, H.P. den Boer, L.C., Dings, J., Bruinsma, F. and Koetse, M. (eds.), *The Price of Transport: Overview of the Social Costs of Transport*, CE Delft ([www.ce.nl](http://www.ce.nl)).
- Varian, H., Litan, R., Eder, A. and Shutter, J. (2002). "The net impact study: the projected economic benefits of the Internet in the US, UK, France and Germany". University of California, Berkley, Working Paper.