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Benefits and Costs of the Infrastructure Targets for the Post-2015 Development Agenda

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Post-2015 Consensus

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Highlights

By the end of June 2014, the Outcome Document of the Open Working Group on Sustainable Development Goals (SDGs) stated as an ICT goal to "significantly increase access to ICT and strive to provide universal and affordable access to Internet in LDCs by 2020" (SDG Goal 9C). Despite its attractive simplicity, this goal faces serious problems with respect to measurability given its vague wording. In addition, the target seems to imply universal access to the Internet in five years' time, which may be unrealistic.

In this light, we propose and examine more precise targets with aims of improving the impact and measurability of the SDG goals. In particular, we focus on targets related to broadband coverage and examine global world targets as wells as achieving these targets in the developing regions of the world. The main proposed targets are:

- Increase World penetration of Fixed (Mobile) broadband by three-fold by the year 2030 (from 10% in the year 2014 to 30% in 2030 for the case of fixed broadband, and from around 32 to 90% for mobile broadband).
- Increase penetration of Fixed (Mobile) broadband by three-fold in developing regions of the world (from 6 to 20% for fixed broadband, and from 21 to 60% for mobile broadband)
- Achieving universal Fixed (Mobile) broadband penetration by the year 2030

Two different methodologies to assess the benefits were used, and the B/C ratios of the main targets discussed in this paper shown in the table below:

B/C 3% Disc. Factor	**Conservative Scenario (1st Methodology)**		**Conservative Scenario (2nd Methodology)**	
Increase by three-fold World Fixed (Mobile*) Broadband penetration	12.25	(13.00*)	16.20	(29.42*)
Increase by three-fold Fixed (Mobile*) Broadband penetration in Developing Regions of the world	13.64	(14.41*)	15.23	(21.74*)
Achieve Universal Fixed (Mobile*) broadband penetration by 2030	3.02	(11.44*)	9.85	(28.79*)

Within the focus area of ICT infrastructure goals the target that has the best benefit-cost ratio (robust to both methodologies of assessing benefits) is:

- Increase mobile broadband penetration around three-fold in developing regions of the world (with B/C ratio ranging from 14.41 to 21.74)

We also believe, given the economic tradeoffs, the following are valuable targets within this focus area:

- Increase Global Fixed broadband penetration around three-fold with B/C ratio ranging from 13 to 29.42 (depending on how benefits are calculated).
- And if, universal broadband penetration goals are to be considered, we believe that mobile broadband seems the most cost effective solution with a B/C ratio of 11.44 (and a ratio of 28.79 according to the second methodology for benefits calculation).

Our analysis shows that the following targets are relatively ineffective or there is large uncertainty in the benefit-cost ratio:

- Universal Fixed Broadband coverage by the year 2030 (with a B/C ratio ranging from 3.02 to 9.85)
- And, given the vague wording, "Significantly increase access to ICT and strive to provide universal and affordable access to Internet in LDCs by 2020" (UN 2014, Outcome Document of the Open Working Group on Sustainable Development Goals)

It is important to note that this is a first attempt at estimating benefit-cost ratios for ICT infrastructure goals at a global scale. There are important challenges when attempting to conduct a Cost Benefit Analysis (CBA) of ICT infrastructure that by its mere nature, has important spillovers in all economic activity within a country. In particular, for the case of broadband many simplifying assumptions had to be made in order to calculate the cost of deploying infrastructure at a global level. These assumptions represent an important caveat when interpreting the results because the cost of deployment will vary among countries given differences in technology, geographical situations and market conditions. Secondly, there is much debate on how to calculate the benefits of ICT infrastructure given its spillovers on GDP. The latter has opened the floor for a vast research agenda in the past few years, and for the sake of the present CBA analysis, the impact of broadband penetration on GDP growth has been used to map the economic spillovers.

Introduction: The importance of information communication technologies (ICTs) for development

Expanding affordable access to information communication technologies (ICTs) infrastructure has become a priority for policy makers, both in developing and developed countries, as ICTs are important enablers for social inclusion and economic development. Besides representing an important sector, ICTs have an impact on economic growth and have strategic spillover effects on other sectors by creating jobs and fostering innovation.

ICT infrastructure has an impact on growth through several channels: productivity gains, enhanced innovation and new ways to market goods and services, employment and firm creation, among others (Pepper et al, 2009). The social inclusion dimension of extending ICTs is the potential to offer services (e.g. health, education and e-government, etc.) to all communities, however remote.

The 2008 OECD Seoul Declaration of the Future of the Internet Economy stated how ICTs, and in particular the Internet, will strengthen the capacity of countries to improve the quality of life of its citizens (OECD, 2009a). For instance, the Internet Economy provides new opportunities of employment, enables civic engagement, empowers consumers, and promotes a global information society based on fast secure and ubiquitous networks connecting billions of people. This declaration recognized the importance of fostering a competitive environment in order to expand Internet access to all.

For the reasons stated above, it is reasonable that ICT infrastructure deployment has been embedded in the past Millennium Development Goals (Goal 8F), as well as in the current draft of Sustainable Development Goals for the Post-2015 Agenda. However, the ICT goals are currently stated in a broad way (e.g. "increase availability of ICT infrastructure") without specific targets of infrastructure services penetration. This vague wording of the targets may potentially render these development goals less binding, though unintentionally. Because of this, the current paper proposes and discusses very specific goals in terms of ICT infrastructure.

Road Map of paper

In order to undertake any cost-benefit analysis, the first step would be to delineate the ICT infrastructure goals; hence Section 2 of the paper involves a discussion of the goals and targets that are currently being discussed as part of the Post-2015 Development Agenda. Targets should be specific, realistic and measurable as to maximize their impact. In the present study, for the sake of being able to conduct a cost benefit analysis, and given the spillovers that broadband has on the rest of the economy, the targets are mainly focused on fixed and mobile broadband penetration.

The Section 3 of the paper focuses on the methodology to undertake the Cost Benefit Analysis (CBA) of reaching these penetration targets.

Finally once the targets have been defined, the impact of ICT (and in particular broadband) has been assessed through the CBA, Section 4 will discuss what governments can do to foster ICT deployment in order to reach the penetration targets.

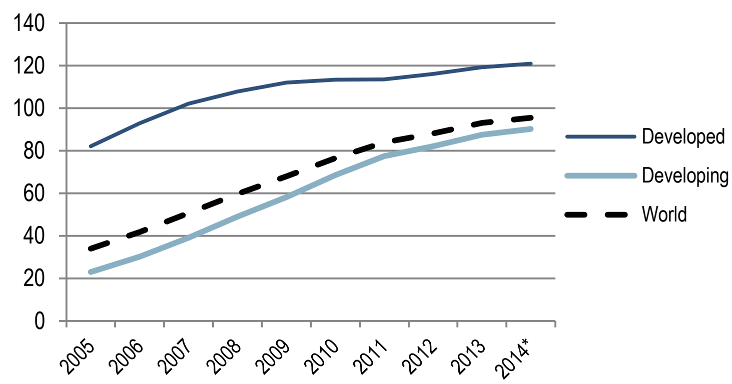
Sustainable Development Goals and targets regarding ICTs

Millennium Development Goals and Post 2015 Agenda: where the targets lie in terms of ICTs?

The Millennium Development Goals were a set of eight goals conceived at the UN Millennium Summit in the year 2000, with the aim of creating "an environment – at the national and global levels alike – which is conducive to development and to the elimination of poverty".[1] What came to be known as the Partnership for Development was embedded in the targets of the Millennium Development Goal (MDG) 8, which addresses aid, trade, debt relief and increased access to essential medicines and new technologies (UN, 2013a).[2]

The International Telecommunications Union (ITU) up to present has followed up on MDG 8F (Develop a Global Partnership for Development), which states: "In cooperation with the private sector, make available the benefits of new technologies, especially information and communication technologies." The ITU uses the following indicators to track this target: telephone lines and cellular subscribers per 100 inhabitants, and computers and Internet subscribers per 100 inhabitants.[3] For example, Figure 1 below displays mobile subscribers per 100 inhabitants (i.e. penetration) in developed and developing regions of the world based on ITU statistics.

Figure 1: Mobile-cellular subscriptions per 100 inhabitants (mobile voice penetration)



Source: ITU World Telecommunication/ICT Indicators database.
Note: The developed/developing country classifications are based on the UN M49, see: http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx

[1] UN Millennium Declaration (A/Res/55/2). 18 September, 2000.
[2] See http://www.beyond2015.org/sites/default/files/global%20partnership%20report.pdf
[3] See http://www.itu.int/en/ITU-D/Statistics/Pages/intlcoop/mdg/default.aspx and http://www.unmillenniumproject.org/goals/gti.htm

The World Summit on the Information Society (WSIS) established in 2004 a Partnership for Measuring ICT for Development given the increased importance of tracking, monitoring and addressing the digital divide. WSIS in 2011 established ICT targets and has tracked them since, although these targets are quite ambitious referring to universal connectivity (refer to Annex 1 for the list of 11 WSIS targets).[4]

There has been extensive debate of what goals should be included in the Post-2015 Agenda with regards to ICTs. In 2012 The Centre for International Governance Innovation (CIGI) and the Korea Development Institute suggested the following ICT goals:[5]

- Universal access to modern telecommunication networks to eliminate exclusion from the new global digital society.
- Universal connectivity in recognition of the growing risk of "digital divide" among and within nations.
- Affordable access to technology and knowledge for enhanced inter-businesses and inter-governmental cooperation.

In 2013, the Report of the "High-Level Panel of Eminent Persons on the Post-2015 Development Agenda" acknowledged that although many countries have different starting points making it difficult to implement "one size fits all" targets, in a few cases, the ambition in the whole world should be the same: to establish minimum standards for every citizen, including that "Everyone should have access to modern infrastructure – drinking water, sanitation, roads, transport and information and communications technologies (ICT)" (UN, 2013b).[6] Furthermore, this document put forward a suggested Goal 8 for the Post-2015 agenda (Create Jobs, Sustainable Livelihoods, and Equitable Growth), where they stress the importance of strengthening "productive capacity by providing universal access to financial services and infrastructure such as transportation and ICT".[7] The wording of these suggested goals seem to indicate universal access of ICTs.

At the end of June 2014, the Outcome Document of the Open Working Group on Sustainable Development Goals (SDGs) mentions in broad terms the importance of expanding access of ICT and building resilient infrastructure in its Goal 9. However, ICT being a General Purpose Technology, it permeates along many other suggested goals (e.g. Goal 4 regarding life-long learning, Goal 5 addressing gender equality, Goal 17 related to building a partnership for development through Technology, among others).[8] The SDGs specifically refer to the access ICT and Internet in Goal 9c, which states: "significantly increase access to ICT and strive to provide universal and affordable access to Internet in LDCs by 2020." The question still lies: much is a "significant" increase? In addition, this target seems to imply universal access to the Internet in five years' time, which may be unrealistic.

[4] http://www.itu.int/en/ITU-D/Statistics/Documents/publications/wsisreview2014/WSIS2014_review_introduction.pdf
[5] http://www.cigionline.org/sites/default/files/mdg_post_2015v3.pdf
[6] See http://report.post2015hlp.org/digital-report-chapter-3.html; http://www.post2015hlp.org/wp-content/uploads/2013/05/UN-Report.pdf
[7] http://www.post2015hlp.org/wp-content/uploads/2013/05/UN-Report.pdf
[8] See http://sustainabledevelopment.un.org/focussdgs.html

Reducing the scope of ICT targets and focusing on Broadband: Why Broadband?

All these different targets, beg the question: which targets to choose in order to undertake a cost benefit analysis of such goals/targets for the post 2015 agenda? In order to do such analysis, targets must be measureable and with a specific time frame. In addition, the scope of the ICT infrastructure goals should be reduced (e.g. broadband, mobile communications) as to improve impact.

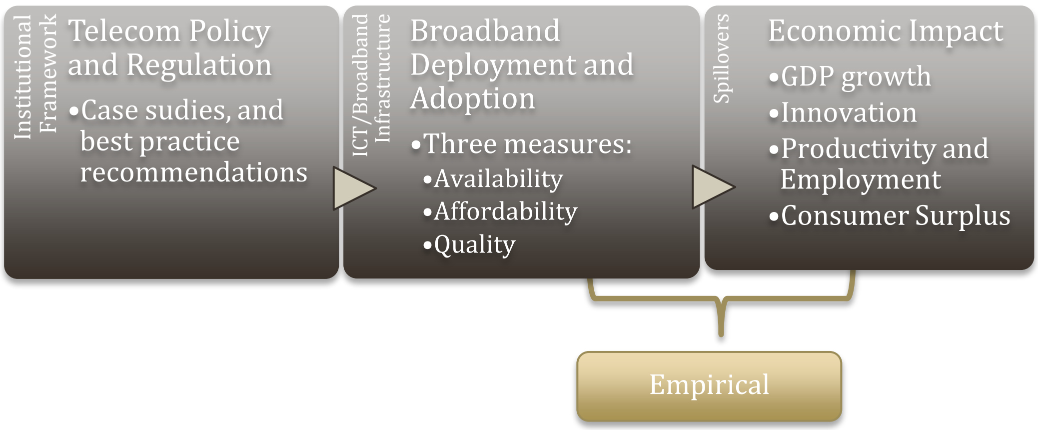
The suggestion is to focus on broadband indicators. The justification is two-fold. First, it is consistent with what is already written in the latest draft of Sustainable Development Goals (SDGs) in June 2014, which specifically states expanding Internet access in its Goal 9c: "significantly increase access to ICT and strive to provide universal and affordable access to Internet in LDCs by 2020." [9] Secondly, broadband is a transformative platform that impacts the ICT sector as well as other sectors of the economy. While there may be disagreement on the level of the economic benefits that can be attributed specifically to broadband, few argue against the fact that broadband has dramatically changed our economies (World Bank 2011).[10]

Broadband can contribute to GDP growth and enhance productivity, as some academic work has pointed out (e.g. a study by Qiang 2009 found that increasing broadband penetration by 10% increases GDP growth by 1.34% in low to medium income economies). It can also create jobs (e.g. a study by Katz et al (2010a) estimated that fulfilling the broadband deployment goals of the German National Broadband Strategy would generate 304,000 jobs in the period of 2010-2014). Finally, broadband may increase consumer surplus as consumers gain access to more services and applications at lower prices. For instance, Greenstein and McDevitt (2009) show that the consumer surplus gains by broadband adoption in the United States between 1999 and 2006 was around USD 7.5 billion.

[9] See http://sustainabledevelopment.un.org/focussdgs.html
[10] http://broadbandtoolkit.org/1.3#note36

The following diagram illustrates a road map for assessing the benefits of broadband infrastructure:

Figure 2: Analytical Framework to assess the impact of broadband on the economy



With this in mind, governments in both developing and developed regions of the world since the 2009 economic crisis, have increased investment in broadband as part of their stimulus packages. For instance, large investments in Broadband Infrastructure have been carried on around the world, and numerous National Broadband Plans implemented. Some examples of investment in networks since 2009 include: the United States invested USD 97.7 billion in network deployment, China has invested USD 7.44 billion in broadband since 2009, Malaysia USD 1.6 billion since 2009, and Australia has invested AUS 43 Billion for the deployment of a fiber network in 8 years (LIRNEasia, 2014a).[11]

However, while ICTs, and in particular broadband, have grown tremendously in the past years, major differences in ICT uptake and use persist. Therefore, what is called the "digital divide" (within and among countries) remains a key impediment to development (WSIS, 2011).

Namely, developing countries are still lagging in broadband deployment, whether it is mobile or fixed broadband. For instance, in 2014 the developing world displayed less than 6.1% fixed broadband penetration versus 27.5% in the developed world, and mobile broadband penetration in developing countries was 21.1% in 2014 compared to 83.7% in the developed world. (Refer to Figures 5.1 and 5.2 in section 2.4).

Given the benefits broadband may bring to developing regions of the world through an increase in employment, productivity and "crowd in" of private investment, the deployment of broadband networks should be a key ingredient in overall development strategies (Qiang, 2010).[12]

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[11] http://broadbandasia.info/wp-content/uploads/2014/03/Ford-Lecture-Session-March-7.pdf
[12] See http://siteresources.worldbank.org/EXTINFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/Resources/282822-1208273252769/Broadband_Investment_in_Stimulus_Packages.pdf

All the above reasons stress the importance of establishing specific Sustainable Development Goals concerning broadband deployment in the Post-2015 Agenda so that developing countries can reap the benefits that this infrastructure can deliver.

What is Broadband and how can it be measured?

Broadband has been defined as an Internet service of at least 256 kbps by the Partnership for Measuring ICT for Development. At present, OECD countries are revising this definition. The World Bank defines Broadband as an ecosystem, which includes users and applications in an interconnected high capacity communications network (World Bank, 2011). [13]

Broadband services can be measured through three main dimensions: 1) availability, 2) quality, and 3) affordability. Hence, in principle, specific targets surrounding broadband access could take into account these three dimensions if reasonable indicators exist.

Targets regarding availability or access of broadband can be formulated around the number of broadband subscription per 100 inhabitants (i.e. broadband penetration rates), or by geographical coverage.

Quality of broadband is typically measured by the download speed of the broadband connection. Broadband penetration targets could have the dimension of speed embedded in them. For instance, the Digital Agenda Europe set the goal of that 100% of EU citizens should have access to basic broadband by the year 2013, 100% of broadband coverage by the year 2020 at 30 Mbps (Megabytes per second), and 50 % of households in the year 2020 should have subscriptions with speeds above 100 Mbps (EC, 2010).[14] Placing targets in terms of speed will have an influence in the network costs that are required to meet them. For instance, broadband speeds above 100 Mbps require upgrades of existing infrastructure to Next Generation Access Networks (NGN) that can significantly increase the costs of deployment.

A caveat should be noted regarding the indicators that may be used to monitor speed targets. There are inherent difficulties surrounding the indicators that measure actual broadband speed (opposed to advertised speeds) as it depends on where servers are

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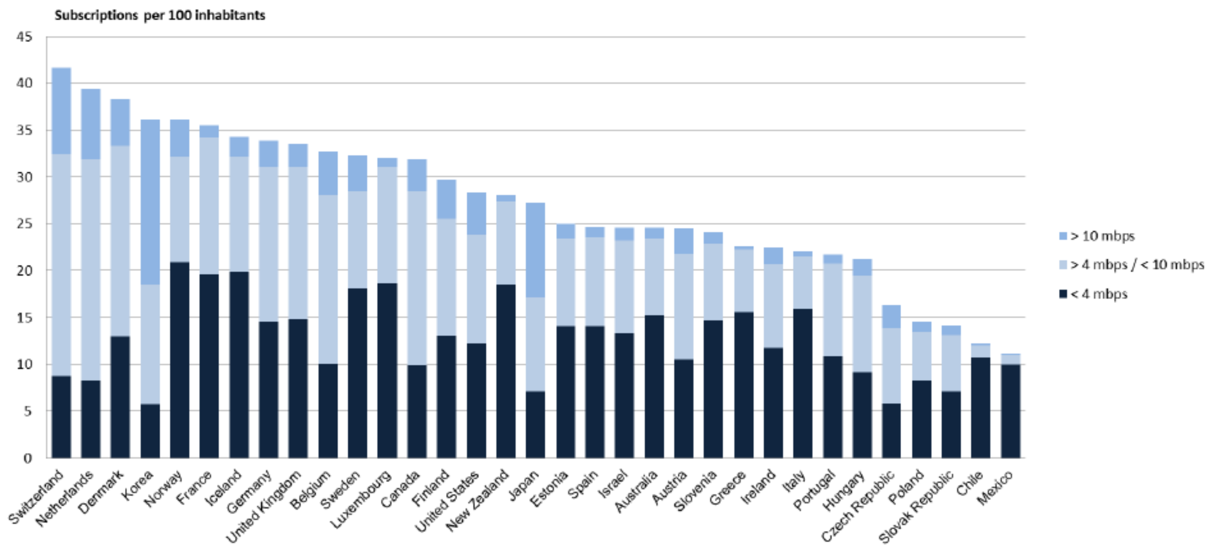
[13] Definitions may vary. For instance, in the World Bank's Broadband Policy Toolkit it says the following: "Despite its worldwide growth and promotion by policymakers, network operators, content providers and other stakeholders, broadband does not have a single, standardized definition. The term "broadband" may refer to multiple aspects of the network and services, including: 1) the infrastructure or "pipes" used to deliver services to users; 2) high-speed access to the Internet; and/or 3) the services and applications available via broadband networks, such as Internet protocol television (IPTV) and voice services that may be bundled in a "triple play" package with broadband Internet access. Further, many countries have established definitions of broadband based on speed, typically in Mbit/s or kilobits per second (kbit/s), or based on the types of services and applications that can be used over a broadband network (i.e., functionality). Due to each country's unique needs and history, including economic, geographic and regulatory factors, definitions of broadband vary widely."

[14] See http://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=sNLXJNSWfJh3TTG5xkL4hrpFLjhwX1HLdWTvCnsvxL1T8zl2SJyb!1619291392?uri=CELEX:52010DC0245R(01)

located when the measure the connection speed, depends of the user's terminal device, and also varies according to the type of broadband connection (i.e. mobile of fixed broadband). Nevertheless there are three main sources that measure broadband speed: Ookla, Akamai and Google.[15]

An example and very useful way of picturing broadband services offered by country is to combine broadband penetration figures with actual speeds observed in the connections as shown in chapter 4 of the OECD Communications Outlook 2013 for OECD countries (see OECD 2013a and Figure 3 below).

Figure 3: Broadband penetration rates by speed tiers, 2012



Source: OECD 2013a.
Note: Based on OECD subscription data (June 2012) merged with Akamai's actual speed data (2Q 2012).

Affordability of Broadband is measured by prices of broadband service packages. It should be noted that prices of telecommunication services depend greatly in the regulatory framework and competitive conditions of the market in each country. That is, the institutional framework naturally has implications in the telecommunications market structure, and hence, consequences on the availability and affordability of telecommunication services, especially in an industry where the cost structure creates an oligopoly.[16] In this sense, prices of telecommunication services and investment figures may

15 See http://explorer.netindex.com/maps for Broadband speed tests from Ookla

16 For example, in Mexico, the degree of low level of competition in the market and lack of regulation increased prices for the consumers resulted in low penetration levels of telecommunications services, as well as portraying extremely high earnings margins in the for an incumbent telecom operator (e.g. twice as high as OECD average), with the lowest levels of investment per capita in the network. The OECD 2012 Report on Mexican Telecoms sector (OECD, 2012a) states the following in pg. 12: "*The Mexican telecommunications market is dominated by a single company with 80% of the fixed line market and 70% of the mobile phone market. Insufficient competition has resulted in poor market penetration (subscribers per 100 inhabitants) for fixed line, mobile and broadband markets, ranking Mexico 34th, 33rd, and 32nd respectively, of the 34 OECD countries.* ***Relative to other OECD countries, Mexico is ranked last in terms of investment per capita. Profit margins of the incumbent nearly double the OECD average.***"

prove useful indicators of the level of competition and framework conditions of a market. However, the complexity of broadband service plans (e.g. bundles, usage patterns, promotional discounts) makes it difficult to construct indicators to track "pricing" targets at a global scale.

The OECD has made several advances in this area by providing a pricing methodology that incorporates usage baskets (for fixed and mobile broadband) in order to compare prices of broadband services across countries (see chapter 7 of OECD 2013a).[17] However, this methodology requires exhaustive data collection of service plans, so even if it would be desirable that a similar benchmark be made available for developing countries, the data collection exercise would require funds in order to be undertaken. Nevertheless, some telecommunications research tanks in developing regions have attempted to replicate the OECD pricing methodology of telecom services (see Research ICT Africa for African countries and Galperin (2009) for Latin American countries).[18]

What adds complexity to the price comparison of ICTs is the adjustment of quality of these services over time. For instance, the quality features of a broadband service plan in the year 2000 differ greatly from those offered in 2014 (e.g. in terms of speed of the connection, or data allowances). For instance, a 100 Mbps Internet offer perhaps was non-existent some years ago, so comparing offers from, for example 2007 to 2014, in terms of price per megabyte would imply comparing different baskets of products. Research using hedonic regression techniques has recently attempted to tackle this problem.

Existing Broadband Targets proposed by the ITU Broadband Commission in 2010 and where we stand in terms of achieving them by 2015

Efforts to track and establish more precise targets of availability of ICT infrastructure have been numerous in the recent past. With regards to Broadband, perhaps the most precise targets were established in 2010, with the creation of the Broadband Commission within the ITU in order to achieve the MDG 8F by the year 2015 which states: "In cooperation with the private sector, make available the benefits of new technologies, especially information and communications technologies."[19] The Broadband Commission established the following targets:

- Target 1: Making broadband policy universal. By 2015, all countries should have a national broadband plan or strategy or include broadband in their Universal Access / Service Definitions.
- Target 2: Making broadband affordable. By 2015, entry-level broadband services should be made affordable in developing countries through adequate regulation and market forces (amounting to less than 5% of average monthly income).

[17] See http://www.oecd.org/sti/broadband/price-baskets.htm

[18] Note that the reliability of results depends on the data collection exercise. Please refer to http://www.researchictafrica.net/prices/Fair_Mobile.php for Africa, and to http://www.udesa.edu.ar/files/UAHumanidades/EVENTOS/PAPERGALPERIN190410.PDF for Latin America

[19] http://www.broadbandcommission.org/Documents/Broadband_Targets.pdf

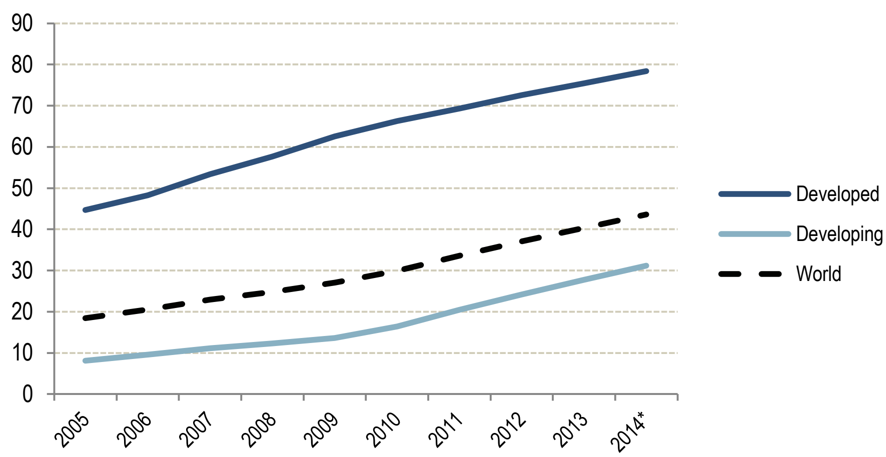
- Target 3: Connecting homes to broadband. By 2015, 40% of households in developing countries should have Internet access.
- Target 4: Getting people online. By 2015, Internet user penetration should reach 60% worldwide, 50% in developing countries and 15% in LDCs.

With only half a year before 2015, the Broadband Commission's Target 1 seems far from being attained since not all countries have a national broadband plan, albeit many countries in the developing world, for instance in Latin America, are recently developing national broadband plans.

As for making broadband affordable (Target 2), given that telecommunication prices depend on third degree price discrimination and bundling techniques, it is hard to ascertain the degree in which the price of broadband service plans has decreased (as discussed in the previous section). Despite all these difficulties, the ITU seems to claim in the MDG report 2014 that: "The price of broadband services has continued to drop. Globally, between 2008 and 2012, fixed-broadband prices fell by 82 per cent, with the biggest drop occurring in developing countries."[20]

Broadband Commission's Target 3 that refers to connecting homes to the Internet also seems unlikely to be fulfilled, as it would require an increase of 10% (from 31% in 2014 to 40% as the target suggests) of households connected to the Internet in the Developing world in less than a year (see Figure 4.)

Figure 4: Percentage of Households with Internet access at home



Source: ITU World Telecommunication/ICT Indicators database.
Note: The developed/developing country classifications are based on the UN M49, see: http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx

[20] See http://www.un.org/millenniumgoals/2014%20MDG%20report/MDG%202014%20English%20web.pdf page 53

As for Target 4, "increasing Internet penetration to 50% in the developing world by 2015", Figure 5.1 and 5.2 display that, regardless of which indicator used for this target (i.e. mobile or fixed broadband penetration), the developing world is far from reaching such goal (with only 6% of Fixed broadband penetration and 21% of mobile broadband penetration in the year 2014).

Figure 5.1: Fixed Broadband subscriptions per 100 inhabitants

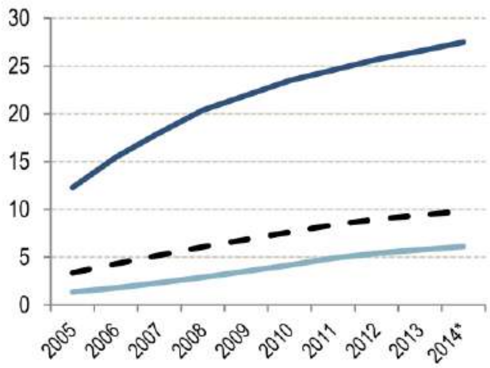
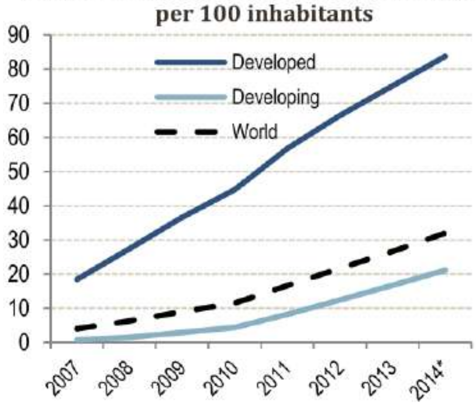


Figure 5.2. Mobile Broadband subscription per 100 inhabitants



Source: ITU World Telecommunication/ICT Indicators database.
Note: The developed/developing country classifications are based on the UN M49, see: http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx

Proposed Broadband Targets for the Post-2015 Agenda

Based on existing goals, such as SDG 9C (significantly increase access to ICT and strive to provide universal and affordable access to Internet in LDCs by 2020), and the goals proposed by the ITU's Broadband Commission, this study focuses on one dimension of broadband, its availability, measured in terms of penetration. This would allow for targets to be concise and measurable.

The specific targets that are suggested and examined in the present paper for the time frame 2015-2030 are the following:

- Increase world fixed broadband penetration by three-fold
- Increase fixed broadband penetration around three-fold in developing regions
- Increase world mobile broadband penetration around three-fold
- Increase mobile broadband around three-fold in the developing regions
- 100% Fixed + Mobile broadband penetration (World and developing regions)
- Universal Fixed Broadband penetration (World and developing regions)
- Universal Mobile broadband penetration (World and developing regions)

A Cost Benefit Analysis (CBA) is conducted for these targets that will allow us to compare by global targets (world penetration) versus regional goals (developing regions), as well as universal access by 2030 compared to increasing 2014 broadband penetration levels by three-fold.

Cost Benefit Analysis of deploying broadband infrastructure

The challenge with the Cost Benefit Analysis (CBA) in the case of broadband infrastructure is twofold. First, it is extremely difficult to calculate the cost of deploying infrastructure at a global level given differences in technologies, geographical situation and market conditions. In addition, the cost of the deployment will depend if governments wish to deploy basic, fast or ultra-fast broadband. Secondly, even under the assumption of having reasonable figures of the cost of deploying infrastructure, there is much debate of how to calculate the benefits of ICT infrastructure given the spillovers it has on GDP. Broadband has become a General Purpose Technology, with significant effects on for growth, but to quantify the externality has been the subject of an entire research agenda over the past few years.

In addition to the challenges of properly assessing costs and benefits, the ICT environment changes rapidly so that during the time frame of analysis (2015-2030), innovations may change the cost structure of broadband networks, especially for wireless technologies. Also, the demand of ICT is likely change in the next fifteen years leading to potential changes in the benefits here calculated. Thus, given technological change, there is inherent degree of uncertainty of ICT infrastructure investments, which may complicate furthermore the cost benefit analysis.

Finally, in order to undertake a cost benefit analysis, it is important to consider which is the status quo (or reference level of deployment) to be considered. We take into account the current broadband penetration levels as the status quo, and we calculate the expected deployment as a function of the stipulated targets.

With all these caveats and considerations in mind, an attempt to measure a cost benefit ratio of broadband infrastructure is undertaken with the aim of being illustrative of the benefits it entails and for it to be comparable among other development goals.

Measuring the Benefits of Broadband Deployment

The following empirical approaches have been taken into account to quantify the impact of broadband on the economy:

- Input-Output tables: What is the impact of broadband infrastructure deployment on output and employment generation within a country?
- Multivariate Regression Techniques: What is the contribution to GDP growth, productivity and employment?
- Consumer surplus perspective: What are the benefits that broadband represents to the end user?

A recent study conducted by Analysys Mason and Tech4i2 for the European Commission (EC) measuring the socio-economic impact of the broadband targets set forth by the EC using an Input-Output methodology as well as an estimation of the consumer surplus gains (EC, 2013). The study estimated that the targets in the Digital Agenda for Europe (DAE), under the assumption of modest state aid (EUR 7 billion to leverage private investment), should create around 2 million jobs and EUR 28.6 billion benefits in consumer surplus (See Table 1). In particular, the study showed that the 27 countries that make up the European Union can expect to receive cumulative benefits of between EUR 200 billion and EUR 600 billion in the period 2012 to 2020, representing a benefit cost ratio of 2.7 and 2.9.

Table 1: Cumulative benefits of high-speed broadband in Europe (EU27 countries), by scenario 2012–2020

Scenario	Total NGA investment (EUR billion)	Input-output benefits (EUR billion)	Jobs created (million)	Consumer surplus benefits (EUR billion)
No State Intervention	76.4	181.2	1.35	26.5
Modest intervention	102.5	270.4	1.98	28.6
Major intervention	211.2	569.4	3.94	31.9

Source: Analysys Mason and Tech4i2[21]

The present study establishes the benefits of broadband deployment focusing in the impact that this infrastructure has on GDP growth. There is a persistent relationship shown in the literature that increasing broadband penetration has a positive economic impact on GDP growth (see Qiang 2009, Czernich et al (2010), Katz (2009, 2010 and 2012), Crandall et al (2007), Katz and Avila (2010), Koutroumpis (2009), among others.)

What are the channels through which Broadband affects economic growth? Katz (ITU, 2012) summarizes three main ones. First, the deployment of broadband technology across firms improves their productivity given the adoption of more efficient business processes. Secondly, extensive broadband deployment increases innovation through new applications and services. Third, broadband leads to a more efficient functioning of firms by maximizing their reach to labor pools or access to raw materials or consumers.

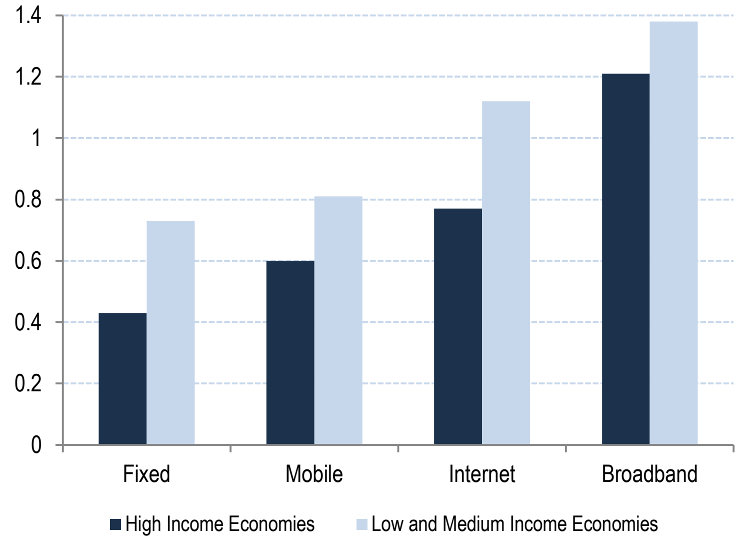
One of the first empirical studies that measured the contribution of broadband to GDP growth was a study conducted by the World Bank (Qiang, 2009). It showed that broadband has the largest impact on growth compared to other telecommunication investments (Figure 6). Qiang (2009) used data for 120 developing countries over the period of 1980-2006 and found that low and medium income countries are in the best position to take advantage of increasing ICT penetration order to foster economic growth. It may be the case that in developing countries broadband could help resolve some pressing problems such as reducing transaction costs. However, other studies suggest the existence of a

[21] http://www.analysysmason.com/About-Us/News/Press-releases1/broadband-benefit-for-EU-Mar2013/

critical mass of this infrastructure meaning that after a certain threshold of broadband penetration (e.g. 30%), the economic impact is larger (Katz –ITU 2012, Koutroumpis 2009).

Figure 6: World Bank 2009 estimates of the effect of telecommunications on Economic Growth

Percentage increase in economic growth for a 10% increase in penetration



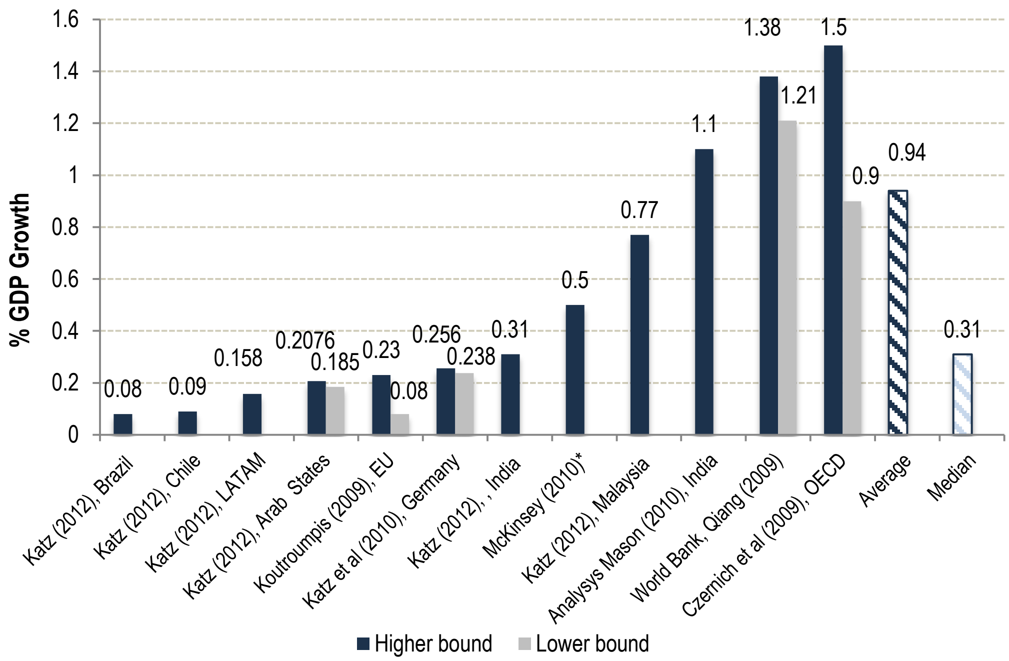
Source: Qiang (2009), World Bank.
Note: All results are statistically significant at a 1% level, except for broadband results in low and medium income economies, which are significant at a 10% level.

There exists general consensus that there is a positive relationship between broadband and growth. Whether this relationship is causal has been tackled by some studies. That is, countries with high GDP growth may also have the means to invest in broadband deployment, hence will exhibit higher broadband penetration levels. On the other hand, it could be that broadband investment leads to GDP growth. The latter issue is known in the literature as reverse causality (i.e. endogeneity concerns) and has been particular addressed in the study by Koutroumpis (2009) that uses a simultaneous equation approach. For this reason, the potential benefits of broadband in the Cost Benefit Analysis of the present paper will be derived by calculating the percentage impact on GDP growth due to broadband using as reference the elasticities presented in the study by Koutroumpis (2009).

The elasticities in Koutroumpis (2009) range from 0.008%- 0.023% increase on GDP growth for each 1% increase in broadband penetration. The latter elasticities depend on initial level of broadband penetration suggesting the existence of a critical mass. Studies conducted by Katz for Latin America have found similar elasticities as Koutroumpis (2009), although Katz (2012) did not use a simultaneous approach given the lack of data.

A summary of empirical studies that have assessed the impact of broadband on economic growth can be seen in Figure 7. As it is shown in the graph, the economic impact of every 10% increase of Broadband penetration on GDP growth varies from 0.08 to 1.5 per cent due to differences in model specifications and datasets used. It should be noted that some of these studies are only done for one country in particular, while other studies include in the data set cross section of countries.

Figure 7: Percentage increase of GDP for each 10% increase in Broadband penetration



Source: Authors' elaboration using the World Bank Broadband Policy Toolkit and ITU (2012); McKinsey & Company analysis Report 2010 for the WEF
http://www.weforum.org/pdf/GITR10/Part1/Chap%205_Fostering%20the%20Economic%20and%20Social%20Benefits%20of%20ICT.pdf

Measuring the costs of broadband deployment

Understanding the costs: how does a Broadband network work?

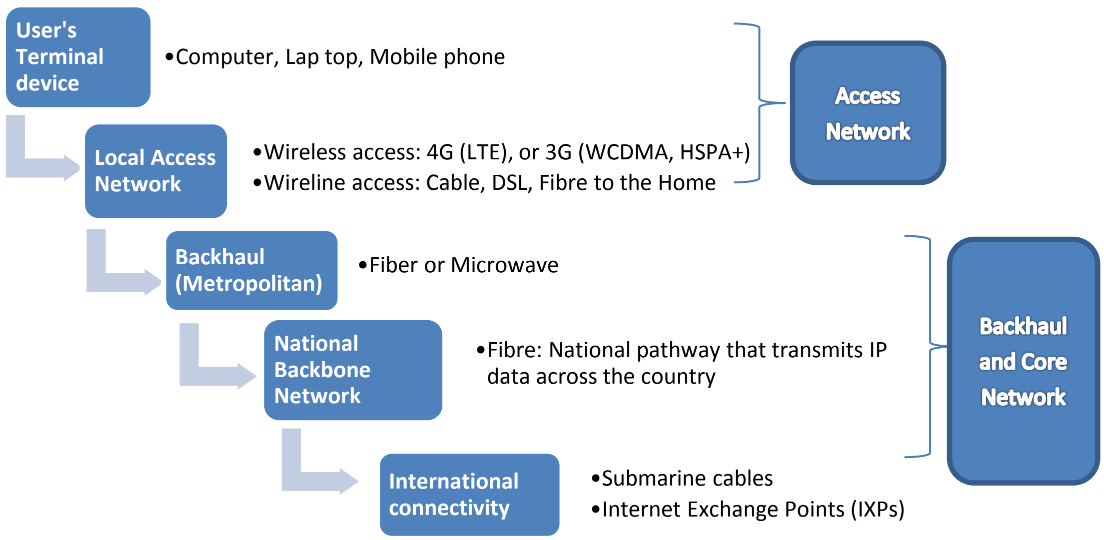
The elements of a broadband network can be classified in the ones belonging to the access network, and those belonging to the core and backhaul network. In a summarized fashion, the access network connects the end user with the nearest network node, and the backhaul and core network are connectivity links over large distances (i.e. metropolitan and national links).

The access network connects the core and backhaul network to the final user, which can be a local wireless or wireline access to the end user. In the case of a wireline (or fixed network) the access network is comprised of a copper, fiber, or a cable that connects the end user to a backhaul node. In the case of wireless network, it is the connection of a cellular tower to the end user using spectrum for this last mile.

The core network is comprised of the national backbone network, usually made out of fiber. The backbone can be thought as a national highway of IP traffic data, which is then connected to international connectivity links (i.e. submarine cables or Internet Exchange Points). The backhaul network is comprised of metropolitan lines that connect the local access network to the national backbone through fiber or microwave links.

Figure 8 illustrates the different elements of a broadband network and the types of technology used for each of these network elements.

Figure 8: Elements of a Broadband network, access and core/backhaul network



Source: Authors' elaboration based on European Union Guide to Broadband Investment (EU, 2011) and TRAI (2014)

An approach taken by policy makers in order to estimate the investment cost required for broadband targets at a national level, is by estimating broadband coverage requirements embedded in the targets specified in their national broadband plans, and then estimating the investment necessary to fulfill them.

The cost of deployment depends on the speed targets embedded in the broadband coverage targets. For instance, Katz et al (2010) in their study of the German Digital agenda found that the cost of deployment per line in order to reach 50 % of German households with ultra-fast broadband (i.e. fiber-to-the-home (FTTH) with speeds up to 100 Mbps) would translate into a cost per line ranging from EUR 1150-1425. On the other hand, according to the targets of the National Broadband Plan of Brazil, the same author found that the cost per basic broadband line at 1 Mbps speeds would cost around USD 300 in case of an upgrade, and USD 450 in case of new line deployment (Katz-ITU, 2012).

In order to determine the costs per line, benchmarking from the deployment experiences of European countries and the United States is useful. It is important to note that these figures may not translate into the reality of individual countries due to differences in labor markets and construction costs (Katz, 2012). However, they provide a useful reference for the assumptions to be taken into account in the Cost Benefit Analysis. Table 2 shows some industry estimates of cost per line that served as reference in the study from Katz et al (2010).

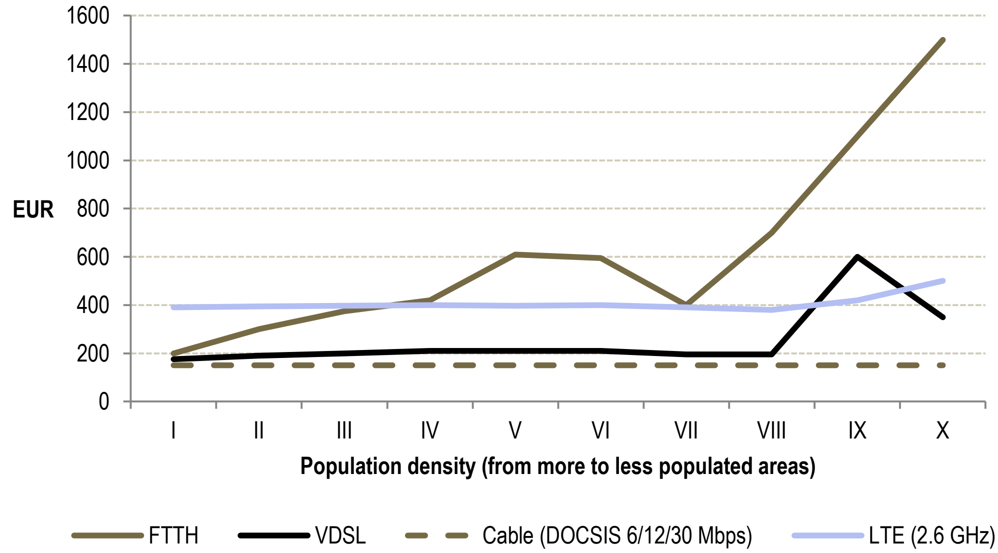
Table 2: Cost per line estimates for VDSL and FTTH upgrades

Sources	Cases	VDSL (EUR)	FTTH (EUR)
Analysis (2006)		300-400	1000
Analysis (2006)	Netherlands		1566
ADL (2009)	Generic	300-450	1150-1700
AT Kearney (2008)	Greece		1206-1525
WIK (2008)		475	
JP Morgan (2006)	Iliad (France)		100-1500
	Net Cologne (Germany)		1000
	Fastweb (Italy)		1200
	Hilegon (NL)		1200

Source: Katz et al (2010)

It is important to note that deployment cost per line will also depend on technology used and population density, as shown in the study of the deployment costs of ultra-fast broadband in Spain by Feijoo and Barroso (2010). For instance, these authors found that wireless technology such as LTE was more expensive than fixed solutions where population density exceeded 3000 inhabitants per square kilometer (Km2), whereas fiber deployments (i.e. FTTH) became more expensive in less dense areas (WIK, 2012). Figure 9 shows the costs of deployment according to population density, where, strata I in the graph corresponds to the most densely populated areas in the country (i.e. more than 10 000 inhabitants per square Km) while strata X to less populated ones (i.e. areas with less than 5 inhabitants per square Km).

Figure 9: Annualized cost per user (EUR), adapted from Feijoo/Gomez-Barroso (2010) study on Spain´s National Broadband Plan



Source: WIK (2012), adapted from Feijoo and Gomez-Barroso (2010)
Note: Strata or Geo-type I (as defined by Authors Feijoo and Gomez- Barroso, 2010) corresponds to geographic areas with more than 10000 inhabitants per km2, strata II refers to 10 000 to 5000 inh./km2, strata III to 5000 to 3000 inh./km2, strata IV to 3000 to 1000 inh./km2 , strata V to 1000 to 500 inh./km2 , strata VI to 500-100 inh./km2 , strata VII to 100-50 inh./km2, strata VIII to 50-10 inh./km2, strata IX to 10-5 inh./km2, and strata X corresponds to less than 5 inhabitants per km2.

The Telecom Regulatory Authority of India (TRAI) has recently (end of September 2014) launched a consultation paper regarding their National Broadband Plan. TRAI calculates that the cost per line (measured in terms of capital expenditure per household) to reach an Indian Household through cable technology (i.e. DOCSIS) was around USD 140 (8450 Rp.), while the cost per line using Fiber-to-the-Home (FTTH) technology was USD 510 in capital expenditures (CAPEX) per line, plus USD 116 in operational expenditures (OPEX) per year (31200 Rp. of CAPEX plus 7089 Rp. annually in OPEX). The latter translates to a total cost per line of around USD 1700.

The challenges of assessing costs in an aggregated form

Although there are examples of CBA conducted for specific investments in broadband infrastructure in a given country, an aggregated or average assessment of costs, to our knowledge has not been done.[22]

There are many challenges of establishing cost per line deployment at a global level, given that it is highly unlikely to have "one size fits all" for infrastructure costs given differences in the type of network being deployed (fixed or mobile), the technology (e.g. if fixed

[22]An example of a CBA conducted for a specific project for fiber deployment is Australia http://www.communications.gov.au/__data/assets/pdf_file/0003/243039/Cost-Benefit_Analysis_-_FINAL_-_For_Publication.pdf

network, differences in costs whether it is cable, DSL, fiber, or combination of fiber and DSL), geographical conditions, price and availability of spectrum, number of mobile towers, degree of infrastructure sharing, etc.

In addition, the cost of network deployment will ultimately depend on the bandwidth requirements envisaged for the network. That is, ultra-fast broadband would probably require investment in fiber-to-the-home technology, which in turn represents much higher costs.

Despite these difficulties, this section will use as a benchmark the cost per line calculated in studies related to network deployment investments within the context of National Broadband plans and digital agendas.[23] Nevertheless, the abovementioned caveats should be kept in mind so as to exert caution when interpreting the results of the Cost Benefit Analysis given the number of simplifying assumptions that were made.

A simplified methodology to assess the Cost Benefit Ratio

A very simplistic model for Cost and Benefit Analysis (CBA) is conducted for the targets specified in Section 2.4. These targets read along the lines of "increasing of broadband penetration X% by the year 2030." [24] Namely, the explicit targets to be analyzed are found in Table 3.

[23] A useful reference to several countries undertaking broadband investments and National Broadband plans to increase quality, price and availability of Broadband can be found in the study undertaken by Harvard's Berkman Center for Internet and Society commissioned by the FCC as a background paper for their broadband stimulus package in 2009. See http://transition.fcc.gov/stage/pdf/Berkman_Center_Broadband_Study_13Oct09.pdf. Another useful reference is the ITU 2012 publication "The impact of Broadband in the Economy" which was a study commissioned to Raul Katz and makes an extensive review of the studies measuring the impact to date, with several tables about investment carried on in different countries. See http://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf.

[24] See OECD 2006 for a Guide of Cost Benefit Analysis http://www.lne.be/themas/beleid/milieueconomie/downloadbare-bestanden/ME11_cost-benefit%20analysis%20and%20the%20environment%20oeso.pdf

Table 3: Targets to be analyzed in the CBA

	Broadband penetration targets for 2030
Target 1	Increase World fixed broadband penetration by three-fold from 2014 levels (from 10% to 30% in 2030)
Target 2	Increase Developing countries' fixed broadband penetration by approx. three-fold from 2014 levels (from 6% to 20% in 2030)
Target 3	Increase World mobile broadband penetration by approx. three-fold from 2014 levels (from 32% to 90% in 2030)
Target 4	Increase Developing countries' mobile broadband penetration by approx. three-fold (from 21% in 2014 to 60% in 2030)
Target 5*	Increase World penetration of Fixed+ Mobile Broadband from 42% in 2014 to 100% 2030 (assuming to reach the target with 1/3 of fixed lines and 2/3 of mobile connections)
Target 6*	Increase Developing countries' penetration of Fixed+ Mobile Broadband from 27% in 2014 to 80% in 2030 (reaching the target with 1/3 of fixed lines and 2/3 of mobile connections)
Target 7	Universal fixed broadband penetration by the year 2030
Target 8	Universal mobile broadband penetration by the year 2030

Note: (*) For targets 5 and 6, (i.e. targets that refer to Mobile plus fixed broadband penetration) it is assumed that 1/3 of the target would be fulfilled with fixed networks and 2/3 with wireless networks

In order to calculate the stream of costs and benefits and to bring them to present value, the first step is to calculate the expected change in terms of subscriptions that are embedded in each target. For this calculation, an estimate of the projected population in 2030 was used in order to derive the number of expected lines to be covered in the world and in developing regions in 2030. United Nations (UN) estimates of world population in 2030 equal to 8,218 million of inhabitants, and the population in developing regions of the world is projected to be equal to 6,952 million people.[25]

With the status quo of penetration, and the proportion of lines to be reached, now it is possible to proceed to calculating the stream of costs and benefits over the 2015-2030 period.

Table 4 displays the mapping of how many lines (subscriptions) would be covered with the eight proposed targets in this paper.

[25] See developing and developed world classification used by the United Nations in http://unstats.un.org/unsd/methods/m49/m49regin.htm#developed and http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx. As mentioned in the note, the population estimates in order to derive the number of lines aimed to be covered for 2030 embedded in these penetration rates targets were retrieved from the United Nations population estimates http://esa.un.org/unpd/wpp/Excel-Data/population.htm

Table 4: Mapping penetration targets to change in lines needed for each target

	Penetration 2014	Subscribers 2014 in millions	Penetration target 2030	Change in penetration 2014-2030	Subs. in 2030** (millions)	Change in subs. 2014-2030 (millions)
Target 1 Fixed broadband (BB) World	10%	711.13	30%	20%	2465.49	1754.36
Target 2 Fixed BB Developing Regions	6%	366.31	20%	14%	1390.36	1024.05
Target 3 Mobile BB World	32%	2315.26	90%	58%	7396.47	5081.21
Target 4 Mobile BB Developing Regions	21%	1265.11	60%	39%	4171.08	2905.97
Target 5* Fixed+ Mobile BB World	42%	3026.40	99%	57%	8136.12	5109.72
Target 6* Fixed+ Mobile BB Dev. regions	27%	1631.42	80%	53%	5561.44	3930.02
Target 7 Universal fixed BB World	10%	711.13	99%	89%	8136.12	7424.98
Target 8 Universal mobile BB World	32%	2315.26	99%	67%	8136.12	5820.86

Note: (*) For targets 5 and 6, (i.e. targets that refer to Mobile plus fixed broadband penetration) it is assumed that 1/3 of the target would be fulfilled with fixed networks and 2/3 with wireless networks. (**) To estimate world and developing region targets in terms of subscribers, the estimated population figures of the UN with constant mortality rate were used.

Calculating the Benefits

The Benefits of the CBA are an imputed benefit of this increase of broadband lines (derived from the change in lines embedded in the targets), and mapped to the potential GDP growth impact using the elasticities from the empirical studies mentioned in Figure 7 (Section 3.2). It is important to note that GDP growth here is used as a proxy of social welfare, although GDP has the caveat of only measuring economic activity and not overall welfare. In light of no other proxies for welfare, in this paper we use the impact of broadband on GDP growth in order to assess the benefits.

In practical terms, the benefits are calculated as follows. Given the broadband penetration target, subscription or lines to be reached are estimated (using population estimates of the year 2030). Then, an incremental benefit of this increase of broadband lines is mapped to a calculated impact on potential GDP growth due to growth on broadband deployment necessary to meet each of the targets.

In all three scenarios (i.e. conservative, medium and optimistic) displayed in Table 6, the benefits are calculated taking into account the elasticity of impact on GDP growth by Koutroumpis (2009) given that it is a conservative estimate compared to other studies, and that the author has taken into account in his methodology endogeneity concerns.[26] This elasticity ranges from 0.008, 0.014 or 0.023 depending of the scenario.

In order to derive the compound annual growth rate (CAGR) of GDP due to Broadband penetration, the formula described in Annex 3 is used, which is based on the formula used in Koutroumpis (2009), and originally presented by Roeller and Waverman (2001).

A growth rate of the economy is assumed for the time period and is applied to the status quo of world GDP, and GDP in developing regions in 2013 (World Bank data), which corresponds to USD 74,899,882 million and USD 24, 487,857 million, respectively.[27] Then, the CAGR of GDP due to broadband is applied to these initial levels of GDP.

Only the incremental GDP resulting from the attributed growth rate derived from broadband penetration during the period 2015-2030 will be counted as a benefit. (For the specific assumptions of growth rates and impact of broadband on growth for each scenario please refer to Annex 4.)

Finally, the flow of incremental GDP from broadband is brought to net present value. The final benefits should account for the externalities of broadband investment all over the economy.

The cost per line assumptions

In practical terms, taking as a benchmark the cost per lines from different types of technology derived from country specific studies in broadband deployment, these costs are extrapolated to the amount of lines to be fulfilled given the targets suggested in the present study. Due to the possible variation of costs given geographical conditions, density of population, type of technology used, and other country specific characteristics, several cost scenarios are analyzed.

In order for the analysis to be feasible, some very simplistic assumptions must be made to grasp a figure of cost per line by type of network (i.e. mobile or fixed broadband). These cost assumptions vary in the three scenarios of the CBA. The different costs of deployment assumed for the different scenarios (i.e. high/medium/low cost of deployment) are based on the cost per line by type of technology displayed in Table 5.

[26] See http://www.sciencedirect.com/science/article/pii/S0308596109000767
[27] The growth rates assumed are based on World Bank projections of the growth of the economy for the year 2016.

Table 5: Cost per line assumptions used for the Cost Benefit Analysis

	Cost per line	Currency	USD (2010)	Source
LTE (Wireless)	400	EUR	509.55	WIK 2012 (based on Feijoo and Gómez Barroso 2010)
	500	EUR	636.94	WIK 2012 (based on Feijoo and Gómez Barroso 2010)
VDSL (Fixed)	300	EUR	382.17	Katz et al (2010) report for Germany and WIK 2012
	400	EUR	509.55	Katz et al (2010) report for Germany
FTTH (Fixed)	600	EUR	764.33	WIK 2012 (based on Feijoo and Gómez Barroso 2010)
	1150	EUR	1464.97	Katz et al (2010) report for Germany
	1425	EUR	1815.29	Katz et al (2010) report for Germany
	1500	EUR	1910.83	WIK 2012 (based on Feijoo and Gómez Barroso 2010)

Source: Authors' elaboration based on WIK (2012) and Katz et al (2010)
Note: Source of annual exchange rate USD/EUR of 0.785 in 2010 is from the Internal Revenue Service (United States).

In the **conservative scenario** (i.e. high cost of deployment), the cost per fixed line is based on estimates presented in WIK (2012) report, an amount to EUR 1500 per line (USD 1910 based on an annual exchange rate of 0.785 in 2010). WIK 2012 report uses data from Feijoo and Gomez-Barroso (2010), which are similar to Katz et al (2010) cost per line of deploying fiber in less dense areas.

The cost per fixed line in the **medium scenario** is based on Katz et al (2010) CBA analysis of Germany's digital agenda targets. The authors attribute a cost of EUR 1150 for a DSL line (USD 1460), whereas they attribute EUR 1300 for a wireless connection.[28] However, we only base the cost of a fixed line connection from this study, given that other sources indicate that wireless lines are less expensive to deploy.[29] Thus the medium and conservative scenario for a wireless line assumes cost estimates presented in WIK (2012) report (i.e. EUR 500 per line, or USD 640).

The **optimistic scenario**, assumes a cost per wireless line of 400 EUR (510 USD) and the cost per fixed line of EUR 600 (around USD 770) based on WIK (2012).

The above cost assumptions seem in line with the cost per line of other sources. For instance, the OECD report 2009 "Network developments in support of innovation and user needs", which was one of the first studies attempting to analyze the cost and benefits of broadband deployment at an international level, assumes costs of EUR 500 per VDSL line and EUR 1500 per Fiber-to the-home line (OECD, 2009b). The OECD 2009 report also mentions that the Dutch regulator OPTA arrived at the estimate of EUR 1000 per fast-

[28] http://www.polynomics.ch/dokumente/Polynomics_Broadband_Brochure_E.pdf
[29] http://www.cio.com.au/article/521796/wireless_networks_can_cost_50_per_cent_less_than_wired_report/

broadband line, while the in the United Kingdom costs per line were estimated around GBP 980. In addition the report highlights that the telecommunications operator, Verizon in the United States, estimated a cost per ultra-fast broadband line of USD 1400 (OECD, 2009b).

Results of the Cost Benefit Analysis

The results of the Benefit-Cost Ratios depending on each scenario are displayed in Table 6.

Table 6: Benefit-Cost ratios depending on three scenarios

B/C	Conservative Scenario			Medium Scenario			Optimistic Scenario		
Disc. Factor	**3%**	**5%**	**8.8%**	**3%**	**5%**	**8.8%**	**3%**	**5%**	**8.8%**
Target 1	12.25	12.05	11.70	21.16	20.71	19.92	52.79	51.38	48.89
Target 2	13.64	13.34	12.82	21.58	21.01	20.02	50.19	48.62	45.88
Target 3	13.00	12.76	12.35	17.51	17.10	16.38	29.47	28.59	27.06
Target 4	14.41	14.08	13.52	17.60	17.13	16.30	27.29	26.41	24.88
Target 5*	7.86	7.72	7.46	12.33	12.04	11.52	25.42	24.65	23.31
Target 6*	6.49	6.35	6.09	9.26	9.00	8.56	17.64	17.06	16.03
Target 7	3.02	2.97	2.87	5.32	5.19	4.97	13.58	13.17	12.45
Target 8	11.43	11.22	10.85	15.46	15.09	14.44	26.13	25.34	23.95

Notes: All three scenarios consider the elasticity of impact on GDP growth from Koutroumpis (2009). The conservative scenario assumes an elasticity equal to 0.008, a high cost of deployment and low expected annual growth rate of GDP. The medium scenario assumes an elasticity of 0.014, medium costs of deployment and medium expected growth rate of the economy. The optimistic scenario assumes an elasticity of 0.023, a low cost of deployment and a high growth rate of the economy. For the explicit assumptions please refer to Annex 4.

The mere nature of the ICT sector with profound technological changes every five to ten years makes it particularly difficult to assess both the benefits and costs of investing in infrastructure. Thus, the 3% or 5% discount rate, as proposed by Copenhagen Consensus Group, is very small compared to what telecommunications companies take into account in their business models when they make investment decisions (i.e. they take into account the WACC varying from 8-14%, in average). For this reason, Table 6 also shows the Benefit-Cost ratio using a discount factor of 8.8% based on a study by WIK Consulting that calculated the cost of Next Generation Network (i.e. fiber and VDSL) deployment of the British Telecom in the United Kingdom.[30]

[30] http://stakeholders.ofcom.org.uk/binaries/consultations/fixed-access-markets/responses/TalkTalk_Group_second_addit1.pdf

We now focus our attention on the conservative scenario given that it underestimates the impact of Broadband on GDP and overestimates the costs of deployment. In all cases, the Benefit-Cost ratios are quite high. For the purpose of comparing these targets with other development targets by the Copenhagen Consensus Group, Table 7 displays only the 3% and 5% discount factor results.

Table 7: Net Present Value (NPV) of Benefits and Costs of Conservative scenario, millions of USD

Conservative Scenario		3%			5%		
TARGETS		**NVP Benefits**	**NPV Costs**	**B/C**	**NVP Benefits**	**NPV Costs**	**B/C**
Target 1	Increase World fixed broadband penetration by three-fold	32,068,336	2,616,850	**12.25**	27,213,741	2,257,829	**12.05**
Target 2	Increase Developing countries' fixed broadband penetration by three-fold	20,841,084	1,527,503	**13.64**	17,587,457	1,317,936	**13.34**
Target 3	Increase World mobile broadband penetration by approx. three-fold	33,176,665	2,553,024	**13.00**	28,109,846	2,202,759	**12.76**
Target 4	Increase Developing countries' mobile broadband penetration by three-fold	21,034,511	1,460,090	**14.41**	17,742,743	1,259,771	**14.08**
Target 5*	100% World penetration of (Fixed+ Mobile Broadband) by 2030	33,426,217	4,252,173	**7.86**	28,311,555	3,668,792	**7.72**
Target 6*	80% (Fixed+ Mobile Broadband penetration) in developing regions	21,236,609	3,270,460	**6.49**	17,904,963	2,821,766	**6.35**
Target 7	Universal fixed broadband penetration by the year 2030	33,460,381	11,075,333	**3.02**	28,339,167	9,555,842	**2.97**
Target 8	Universal mobile broadband penetration by the year 2030	33,440,094	2,924,655	**11.43**	28,322,771	2,523,404	**11.22**

Notes: All currency figures in USD millions. For targets 5 and 6, it is assumed that 1/3 of the target would be fulfilled with fixed networks and 2/3 with wireless networks.

In all three scenarios, the targets related the expansion of broadband penetration (either mobile or fixed) by three-fold in developing regions of the world exhibit the highest Benefit to Cost ratios, or B/C ratios (Targets 2 and Target 4). After these two targets, the next target with the highest B/C ratio is expanding world mobile broadband by three-fold (Target 3). Thirdly, increasing world fixed broadband penetration threefold (from 10-30%, Target 1) also exhibits a large B/C ratio.

Finally, universal penetration goals seem to have to lowest B/C ratios, with the exception of achieving this goal through mobile broadband. For instance, one way of framing this goal is by increasing total (Mobile+ Fixed) world broadband penetration to 100% in 2030 (Target 5), though it should be noted this does not necessarily imply universal broadband coverage as the same subscriber could have both a fixed and a mobile connection. The second way of stating universal coverage is by technology (i.e. fixed or wireless).

A valuable takeaway from the results of the B/C ratios in Table 7 is that given the cost advantages that wireless technologies can have over fixed network deployment, universal penetration goals seem to be better off if they are reached through wireless deployment. In fact, the B/C ratio of achieving universal coverage through mobile broadband is quite high (i.e. 11.43). However, these results depend on the cost assumptions and the available indicators chosen to measure these targets. It should be noted, however, that network deployment targets should be met with the principle of technology neutrality.

The importance of Wireless for the developing world

Wireless technology has emerged as a means to offer broadband, and compared to fixed or wireline technology, the costs savings of deploying such a network are quite significant. Some studies suggest that the cost per user of a wired network may be three times higher than a wireless network (Rahunathan, 2005). The main reason of this cost difference is that in a wireless network, the "last mile" (i.e. the access to the end user in the local network), is shared through a cellular site using radio-electric spectrum. In a fixed wireline network, a cable, for instance copper or fiber, would have to connect the end user to the central. So compared to wired technologies, wireless does not require digging trenches and getting rights of way to install a physical connection to end-users. The latter is translated into a substantial cost reduction for operators. For instance civil engineering costs in a wired network, including trenches, ducts, posts, cable, and rights of way, may represent 30% to 80% of the total network's capital expenditures.[31]

Moreover, LTE wireless technology already achieves mobile broadband connections with speeds of 10-30 Mbps in some parts of the world. It is expected that new innovations in wireless, such as cognitive radio and making available more spectrum available, should ensure that higher speed would be available in the future (LIRNEasia, 2014b).

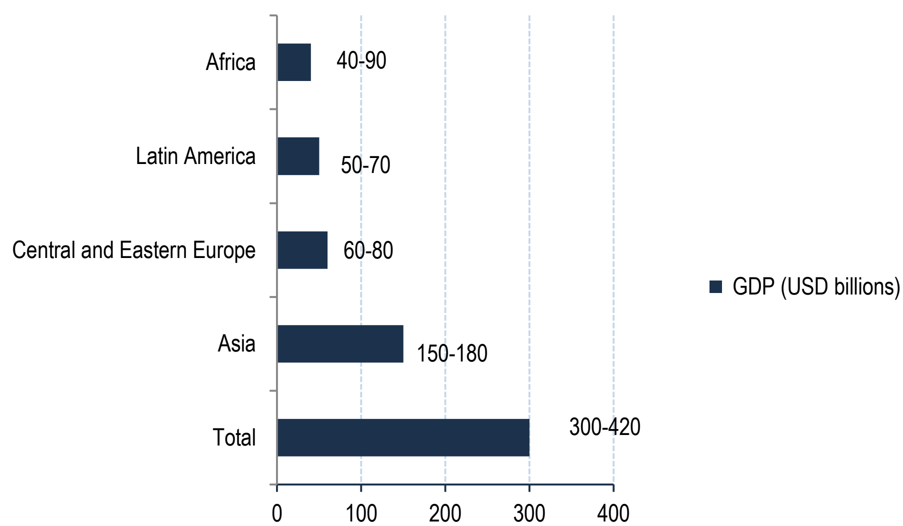
For the case of a country like India, with high population density and prevalent TV networks, cable seems a cost–effective option for broadband deployment (Marcus and Jain, 2010). In addition, as is the case in many developing countries, fixed voice networks are very insipient in India (almost non-existent with only 3% penetration), whereas mobile voice penetration has exploded in the past decade (from 3% in 2003 to 72% in 2011 according to ITU data). The latter makes a strong case for wireless broadband as a cost-

[31] See European Regulatory Group (2007), p.17; Office of Communications (2008), p.40; and OCDE (2008), p.20.

effective solution in India, but also, in many other developing countries with similar characteristics.

In addition to cost savings of wireless technology, a report by McKinsey and Co. in 2010 "Fostering the Economic and Social Benefits of ICT" for the World Economic Forum, estimated that bringing mobile broadband penetration in emerging markets to the levels of penetration of mature markets could add USD 300-400 billion to the world GDP and translate into 10-14 million direct jobs in emerging regions (WEF, 2010). See Figure 10 below.

Figure 10: World Economic Forum Report 2010, Impact of increasing mobile broadband in developing regions, in GDP (USD billions)



Source: McKinsey and Company analysis, from Chapter 1.5 of WEF report "Fostering the Economic and Social Benefits of ICT"
http://www.weforum.org/pdf/GITR10/Part1/Chap%205_Fostering%20the%20Economic%20and%20Social%20Benefits%20of%20ICT.pdf
Note: The figure shows absolute increases in each region. Assumptions are that mobile broadband reaches February 2009 levels of fixed broadband penetration in Western Europe (54%). An increase of 10% of broadband penetration is assumed to leas to 0.5% increase in GDP.

Finally, most of Internet connections in the developing regions of the world are bound to be from wireless devices. An ICT research think tank in Southeast Asia, LIRNEasia, recently pointed out that most people from developing countries get connected to the Internet through mobile phones, and that even though the first wave of broadband was accessed through a computer, more people are getting connected to the Internet through mobile phones (LIRNEasia, 2014b).[32]

[32] LIRNEasia has recently highlighted (September 2014) within the context of a consultation document of India's National Broadband Plans, the importance of wireless networks to boost access in developing countries.

There are interesting examples in Africa and Asia of how mobile Internet access is becoming more and more important for developing countries based on survey data. For instance, in 2012 in Ethiopia and Uganda 81% of users accessed the Internet through a mobile device in the previous 12 months, and around 70% of users in these countries accessed the Internet for the first time using a mobile device. Access through mobile Internet makes sense given that in 2012 only 0.9% and 0.5% of households had a working fixed Internet connection at home in Ethiopia and Uganda, respectively (Research ICT Africa, 2012).

Other examples include Tanzania, Namibia and Nigeria where about 50% of users accessed the Internet for the first time on a mobile phone (Research ICT Africa, 2012). In China by the end of 2012 there were 422 million mobile Internet users (64.4 million more than in 2011), and among the total of Chinese Internet users, 75.4% percent accessed the Internet using their mobile phones (China Internet Network Information Center, 2013).

Sensitivity analysis of the conservative scenario

A sensitivity analysis can be conducted just varying one of the underlying parameters at the time: either the growth rate of the economy, the elasticity of broadband impact on GDP growth, or the deployment cost assumptions. Table 8 shows the main parameters used for each of the scenarios. The sensitivity analysis will be based on the conservative scenario results shown in Table 7 above.

Table 8: Main parameter assumptions by scenario

SCENARIOS	
Optimistic	• High elasticity of the impact of Broadband penetration on growth (0.023) • Low deployment costs (USD 510 per wireless line and USD 770 per fixed line), • High growth rate of the economy (3.5% for World, and 5.5% for developing regions)
Medium	• High elasticity of the impact of Broadband penetration on growth (0.014) • Medium deployment costs (USD 640 per wireless line and USD 1460 USD per fixed line) • Medium growth rate of economy (3% for World and 5% for developing regions)
Conservative	• Low elasticity of the impact of Broadband penetration on growth (0.008), • High deployment costs (USD 640 for wireless technology and USD 1900 for fixed line), • Low growth rate of economy (2.5% for the World and 4.5% for developing regions)

The results of the Benefit to Cost ratios in Table 7 change slightly when different elasticities of broadband impact on economic growth are assumed. For instance, when assuming a medium elasticity (0.014%), the ratios increase around 8%, whereas the elasticity of the optimistic scenario (0.023%), these improve around 21%. If one takes into the elasticity presented in Qiang (2009), the ratios greatly improve (almost 2.5 higher).

If one assumes a medium growth rate of the economy as a whole (instead of a small growth rate) the benefits increase. In this case ratios improve around 14% (depending on the target). A high growth rate of the economy would lead to an increase of these ratios in the magnitude of 23 to 30 %.

When varying the assumed costs, the ratios can greatly improve. If we change to the optimistic scenario costs (keeping constant the conservative scenario growth rates and assumed elasticities), the ratios improve around 25-147%. If we assume the costs per line of the medium scenario, the ratios improve 16-30%.

Robustness check: A different methodology to assess the benefits

The CBA analysis in Table 7 the benefits are calculated using Roeller and Waverman´s (2001) formula of the Compound Annual Growth Rate of the economy attributed to broadband. This derives from the econometric estimations of broadband impact with certain time frames. In a way, by using this formula, there is a tendency to underestimate greater changes in the levels of broadband penetration for the same time period.

Given the abovementioned caveat, another way of calculating the benefits, (instead of using Roeller and Wavermans' (2001) formula, see Annex 3), is to take the elasticity estimated by Koutrompis (2009) and multiply it by the percent change in broadband penetration given the established penetration targets. Afterwards, this "percent impact" on the economic growth is distributed evenly across the period (i.e. divided by the number of years, which in our case is 16). This "yearly percent impact" on the GDP growth will be added to the baseline assumed GDP growth rate. Then we proceed to only take into account as benefits the incremental GDP derived using this formula.

The advantage of this method is that it allows accounting for greater changes in the penetration levels embedded in the targets (as opposed to the method using the Compound Annual Growth Rate attributed to broadband of Roeller and Wavermans' formula). The caveat is that the benefits may be overestimated given that the elasticity of the impact of broadband penetration on economic growth (which is a local concept), is applied linearly over the whole period. In contrast, the benefit calculation used for Table 7 implicitly assumes by the formula non-linearity of the benefits.

The results of the Benefit-Cost ratios of this methodology are displayed below. In this case, the highest ratios are those of Targets 3, 4 and 8, which all relate to increases in mobile broadband penetration (that by cost assumptions, is much cheaper to deploy than fixed networks). It should be stressed that the target that is robust to both methodologies is to increase mobile broadband penetration by three-fold in the developing world (Target 4). In addition, if universal targets are desired, this is best achieved with mobile broadband (Target 8).

Table 9: CBA using different methodology to assess the benefits

Conservative Scenario		3%			5%		
TARGETS		**NVP Benefits**	**NPV Costs**	**B/C**	**NVP Benefits**	**NPV Costs**	**B/C**
Target 1	Increase World fixed broadband penetration by three-fold	42,390,809	2,616,850	**16.20**	36,066,886	2,257,829	**15.97**
Target 2	Increase Developing countries' fixed broadband penetration by three-fold	23,256,962	1,527,503	**15.23**	19,657,414	1,317,936	**14.92**
Target 3	Increase World mobile broadband penetration by approx. three-fold	75,098,009	2,553,024	**29.42**	63,424,511	2,202,759	**28.79**
Target 4	Increase Developing countries' mobile broadband penetration by three-fold	31,739,474	1,460,090	**21.74**	26,698,437	1,259,771	**21.19**
Target 5*	100% World penetration of (Fixed+ Mobile Broadband) by 2030	74,316,157	4,252,173	**17.48**	62,773,903	3,668,792	**17.11**
Target 6*	80% (Fixed+ Mobile Broadband penetration) in developing regions	37,104,968	3,270,460	**11.35**	31,129,633	2,821,766	**11.03**
Target 7	Universal fixed broadband penetration by the year 2030	109,094,260	11,075,333	**9.85**	91,588,082	9,555,842	**9.58**
Target 8	Universal mobile broadband penetration by the year 2030	84,188,760	2,924,655	**28.79**	70,978,911	2,523,404	**28.13**

Note: (*) For targets 5 and 6, (i.e. targets that refer to Mobile plus fixed broadband penetration) it is assumed that 1/3 of the target would be fulfilled with fixed networks and 2/3 with wireless networks.

Institutional framework as the foundation to reap the benefits of ICT

Now that we have established the importance of broadband deployment, and the cost effectiveness of investing in infrastructure, this section discusses some framework conditions that may help countries reach penetration targets so that societies enjoy the full benefits of ICT infrastructure.

Given the importance of ICTs for development, what should governments do to foster ICT networks? The World Bank points out that governments should seek that markets work more efficiently, and should ensure equitable ICT access for all (World Bank, 2011). Some key enablers for ICT infrastructure development as a way to promote efficiency and extend ICT coverage can be summarized below:

- Competition in the telecommunications service provider market
- Policies that foster the access and adoption of ICTs
- Development of applications and local content
- Government aid to extend ICT network coverage and provide services in underserved areas (i.e. investment in strategic parts of the network)

Pepper et al (2009) mention two key elements to foster ICT access and use: 1) the ecosystem, such as ICT market competition and ICT policies and regulation, and 2) infrastructure, which includes physical infrastructure (international connectivity, domestic networks), as well as ICT skilled human capital in the country. That is, in order to foster ICT infrastructure, policy makers should strive to tackle both institutional and regulatory framework conditions as well as to provide incentives for network deployment. In addition, a crucial ingredient to reap the benefits of ICT in policy design is enhancing ICT use and adoption (through digital-alphabetization programs, development of local content and apps, etc.).

With this in mind, the main question that will be briefly addressed in this section is: how can governments help drive the cost of networks down while providing incentives for broadband deployment?

Specific policy and regulatory interventions to foster network deployment

Deployment of broadband infrastructure is an expensive undertaking given the large fixed costs that it entails, so any measures that reduce the cost of deployment should help public funds have a greater impact as well as rendering investment by private operators more attractive. In general, any policy or regulation that reduces deployment costs should maximize the social impact of the investment.

Thus, even though the public sector may have a central role in fostering broadband deployment, it should by no means be a substitute for the market. On the contrary, governments should encourage private investments by establishing a level playing field for all competitors in the market through rules that reduce entry barriers and costs of network deployment.

In order to reduce entry barriers and provide incentives to invest in networks, governments can take the following set of actions:

- Institutional framework to tackle anticompetitive behavior
- Regulatory telecommunications framework focused on wholesale remedies
- Efficient interconnection policies (wholesale access obligations, as well as access fees regulated at costs)
- Efficient spectrum management
- Re-use of existing infrastructure (e.g. ducts and trenches from other utilities as well as infrastructure sharing policies among established operators)
- Streamlining the provision of rights of way when deploying infrastructure (this may depend of municipal authorities)
- State aids in broadband infrastructure should be analyzed as to not crowd out private investment, the tendering process should be transparent and technology neutral, and state aids should be accompanied by open access regulations to the subsidized networks

Regulations that may help reduce the cost of network deployment

Bottlenecks in telecommunications networks exist where network facilities would be uneconomically duplicated, and where entrant must purchase services from incumbents (e.g. wholesale broadband access) (OECD, 2012). The aim of ex-ante regulation is "to prevent a dominant operator from engaging in anti-competitive practices such as "deny, delay and degrade" tactics in the provision of essential wholesale access products to new entrant competitors" (OECD, 2012). Thus, regulators set ex-ante conditions of access to network elements of the incumbent or dominant player's network.[33]

In the case of fixed network deployment, it has been estimated that the largest costs are associated to the access network. For instance, construction costs for Fiber-to-the-Home networks are estimated at around 60-80% of total roll out costs (OECD, 2011).

As incumbents may have a significant advantage over entrants because of their historical monopoly position and existing rights of way, European and OECD countries have recognized that ex-ante regulations need to be put in place in order to reduce bottlenecks. There regulations include: 1) ensuring municipal access to rights of way, at reasonable prices, for new entrants and incumbents, 2) ensuring access by new entrants to existing ducts/poles of both network operators and utility companies and municipalities, 3) regulations to ensure the sharing of access to the inside wiring of apartment buildings and homes, 4) facilitating access to street cabinets, and 4) where mandated, ensuring wholesale access is provided on a non-discriminatory basis (OECD, 2011). For instance, Korea and Hong Kong, China, both leaders in fiber deployment in the world, have promoted open access to the inside wiring of apartment buildings which in turn has facilitated infrastructure competition (OECD, 2013b).

With regards to wireless networks, the access network, or "last mile", consists basically of antennas, towers and spectrum. Since, as discussed before, wireless networks may become very important to reach broadband penetration targets in developing regions of the world, it is worthwhile to focus on two important elements that may drive the cost of deploying wireless networks down: effective spectrum management and infrastructure sharing.

Spectrum management

Wireless technologies require as an essential input spectrum, thus spectrum management is crucial in promoting market entry. Efficient spectrum management not only means to make spectrum available, but also to ensure its efficient allocation so that players in the market have incentives to deploy networks and effectively compete in the market. Allowing the accumulation of spectrum holdings by new entrants (e.g. by reserving blocks of

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[33] These conditions include the fees, and a typical example of ex ante regulation in Europe and OECD countries is wholesale interconnection of networks. (For example, in Europe mobile termination (i.e. interconnection) fees are regulated ex ante by the NRAs following a Long Run Incremental Cost (LRIC) methodology, given that all mobile operators have a monopoly in the termination of their calls.)

spectrum for entrants in auctions, or having spectrum caps for incumbents) has been useful tool to increase competition in telecommunications markets.

Infrastructure sharing

Infrastructure sharing is becoming more and more common in European and OECD countries, especially in rural areas (OECD, 2012b). For instance, Vodafone and Telefonica have reached an agreement of sharing infrastructure in European markets wherever both firms are present (OECD, 2014a).

There are two main infrastructure-sharing agreements: passive, which involves the sharing of masts, towers or sites, and cabinets, and active infrastructure sharing (involving antennas, nodes and even spectrum). Passive infrastructure sharing is common in all European countries (BEREC, 2011). The main benefits of passive infrastructure sharing are greater geographical coverage and cost savings. In fact, Analysis Mason (2010b) estimated that wireless infrastructure sharing might reduce operators' capital expenditures in 30% and 15% of operational expenditures.

One of the most important elements in the development of a mobile network is where towers and antennas are placed. To promote the entry of new competitors into the market, regulatory authorities in various countries have implemented policies aimed at fostering site and tower sharing among mobile operators.

The importance of an independent Regulator and Competition Authority

There should be an institutional and regulatory framework to tackle anticompetitive behavior, and to enforce ex ante regulation in a sector where the nature of the cost structure naturally results in an oligopoly market. In most OECD countries, regulation of the telecommunications sector usually includes ex-ante and ex-post (competition law) regulation (OECD, 2012). In this sense, an independent National Regulatory Agency and Competition Authority recover great importance, as the both play an essential role in facilitating sector development and growth by providing regulatory certainty and a level playing field in the market. That is, the rules of the game have a repercussion on market entry, and thus in the incentives to invest in network deployment both by new entrants as well as existing operators.

A well-designed independent regulator should enable clear separation between industrial policy and sector competition regulation. This would reduce exposure to political drivers when the regulator takes actions to foster competition. It becomes even more relevant in a setting where there is public ownership of telecommunications operators given that an independent regulator may avoid conflicts of interest (OECD, 2014a).

In the same vein, Competition Authorities should be independent from government as to avoid political interference. A collegial body with fixed terms should be desirable in order to avoid dismissal without proper justification of commissioners by the executive branch of government.

In addition, both the national regulatory agency as well as the competition authority should have enforcement powers over their decisions, meaning reasonable sanctioning powers in order to foster compliance of regulation and competition measures.

State Aid when funding broadband investment projects and open access obligations

Despite the advantages of an active role of government in promoting wide and fast broadband network deployment, there always exists a risk of crowding out private investments. The 2009 European Commission's state aid guidelines for broadband investments provide the safeguards that should be put in place in order to promote competition while fostering rapid roll-out of broadband networks (EC, 2009).

Several broadband state aid projects within the European Union have been granted over the past few years, and all of them comply with the EC Broadband Guidelines.[34] Table 10 shows some of the projects that have been funded.

Table 10: Examples of Broadband State Aids in the European Union, 2013 -2014

Country	Name of Broadband Investment project	State aid	Duration
Greece	Prolongation of Broadband Network Development in White Rural Areas of Greece[35]	EUR 161.077 million	2014-2015
Portugal	High-speed broadband in Portugal[36]	EUR 106.2 million	2014-2015
Finland	Modifications in the aid scheme concerning high-speed broadband construction in sparsely populated areas in Finland[37]	EUR 160 million	2014-2015
Germany	NGA Sachsen-Anhalt [38]	EUR 125 million	2014-2017
Bulgaria	Broadband network project in Bulgaria[39]	BGN 39 million	2013-2015
Rumania	Ro-NET project [40]	EUR 84 million	2013-2015
Ireland	Next Generation (backhaul) Network (NGN) alongside a gas pipeline in Galway and Mayo [41]	EUR 10.06 million	2013-2028
Poland	Regional broadband network of Łódź-2ndstage [42]	EUR 6 million	2013-2015
Germany	Entwicklungskonzept Brandenburg Glasfaser 2020 II [43]	EUR 54 million	2013-2015

[34] See all State Aids granted for Broadband Networks in the European Union in the following link: http://ec.europa.eu/competition/sectors/telecommunications/broadband_decisions.pdf
[35] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2014:050:FULL&from=EN
[36] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2014:117:FULL&from=EN
[37] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2014:117:FULL&from=EN
[38] http://ec.europa.eu/competition/state_aid/cases/248494/248494_1501760_125_3.pdf
[39] http://ec.europa.eu/competition/state_aid/cases/247751/247751_1538299_118_2.pdf
[40] http://ec.europa.eu/competition/state_aid/cases/250354/250354_1501667_115_2.pdf
[41] http://ec.europa.eu/competition/state_aid/cases/243213/243213_1504550_221_2.pdf
[42] http://ec.europa.eu/competition/state_aid/cases/247159/247159_1484945_88_2.pdf
[43] http://ec.europa.eu/competition/state_aid/cases/248698/248698_1471122_81_2.pdf

The EC Broadband Guidelines establish that broadband stimulus should be granted where market failure has been established, for instance where no service available or where coverage is insufficient. In addition, the Guidelines state that publicly funded broadband infrastructure projects should commit to open access to all operators with public documentation of the terms and conditions of access as well as transparent pricing to ensure non-discrimination (LIRNEasia, 2014b). Open access refers to the mandated transparent and non-discriminatory wholesale access as a condition to be awarded a subsidy for network deployment (OECD, 2013b).

In particular, all State Aids in the European Union comply with paragraph 79 of the Broadband Guidelines, which refers to open access obligations of the subsidized network. For instance, the United Kingdom in February 2012 launched a EUR 1.8 billion state aid for Broadband delivery in order to comply with the Digital Agenda Europe and the National Broadband Strategy of the UK. The aid followed an open and transparent tender process, and one of the stipulated conditions was that in exchange for receiving state support, the direct beneficiaries of the scheme would provide third parties with effective wholesale access for seven years. Specifically, the State Aid mandated the right to use ducts or street cabinets in order for third parties to have access to infrastructure of the Next Generation Access Network (NGA). This open access clause becomes crucial as it ensures that existing access seekers can migrate customers to an NGA network as soon as the subsidized network is in place. This way existing networks can plan their own future investments without suffering a competitive handicap (EC, 2012).

What type of broadband infrastructure should governments fund in order to drive network deployment costs?

An important role of the government is to ensure that high-speed robust core backbone networks are available across the country. In many cases, a clear and predictable regulatory environment will attract private investment to build core broadband networks; in others, public investment may be required to generate the externalities that core networks offer (Pepper et al 2009). For instance, South Korea, a world leader in Broadband penetration and speeds (as well as one of the first countries to establish a National Broadband Plan), provided subsidies to operators investing in the fiber backbone that connected significant cities within the country (Marcus and Jain, 2010).

Many governments have opted to provide funds for international connectivity (i.e. submarine cables or Satellite links), the core and backhaul network, internet exchange points, as well as investing in the access network in remote areas.

A large number of broadband investment projects funded by public entities in Europe are centered in investments on elements of the backhaul and core network (Guide to Broadband Investment EU, 2011). The reasoning behind this is that the backhaul/core network connects large areas and it is cost effective way to ensure coverage of a large amount of users. However, the effectiveness of these investments relies on the access infrastructure, as the last mile to the user may be the bottleneck. Thus, authorities should strive to ensure that there is sufficient competition in the access network (EU, 2011).

What is the role of international organizations in helping developing countries expand ICT services?

For one, international organizations can be platforms of sharing information and benchmarking of best practices regarding regulation and policies that work to provide incentives for network deployment (OECD, 2009a). Secondly, the donor community can help with aid for the investments in ICT infrastructure. For instance, the World Bank has financed strategic investments for key parts of broadband infrastructure in developing countries (i.e. submarine cables, backbone networks, etc.). Currently, the Inter-American Development Bank is financing critical infrastructure for broadband deployment in Latin America.

Conclusions

The aim of this study was to suggest possible ICT infrastructure targets to be included in the Sustainable Development Goals agenda, accompanied of a Cost Benefit Analysis of these targets. The suggested targets focused on broadband availability measured in terms of penetration. Existing literature has already generated considerable amount of evidence of the positive spillovers that broadband has on the economy (ITU, 2012), and policy makers in both the developed and developing regions of the world are taking into account ICT when their development strategies as well as stimulus packages.

The Cost Benefit Analysis conducted in this paper should be interpreted with much caution as it is based in a series of over-simplifying assumptions regarding they cost per line per type of technology to achieve network coverage. The intention was to provide some sort of reference when comparing ICT infrastructure targets with other development targets in the Post-20145 Agenda. In addition the broadband deployment targets are formulated according to the existing indicators in this domain.

With these caveats in mind, in general the targets related to the expansion of mobile broadband penetration by three-fold at a global level or in developing regions exhibit the largest Benefit-Cost Ratio (Targets 3-4). In particular, the highest B/C ratio that is robust to different methodologies of assessing the benefits are related to expanding mobile broadband in developing regions by three-fold (i.e. Target 4, with a B/C ratio of 14.41 and 21.74, depending on the way the benefits are assessed). Secondly, expanding world mobile broadband penetration threefold (from 32% to 90% as expressed in Target 3) also exhibits a large B/C ratio of 13 and 29.42 (according to both methodologies to assess the benefits).

Additionally, if policy makers wish to insist upon universal broadband penetration goals, a discussion on how to measure this target should be undertaken (i.e. if the targets should be measured with indicators according fixed or mobile broadband, and if indicators should be measured at a household or individual level). If we consider universal broadband penetration to be reached by either fixed or mobile networks, some takeaways can be drawn from the analysis: it seems that given the cost advantages that wireless technologies have over fixed networks, targets aimed to achieve the universal availability of broadband seemed to be better off if they are reached through wireless technology, (at least in the developing regions of the world). In fact, the B/C ratio of achieving universal mobile broadband penetration by the year 2030, Target 8, is quite high (i.e. 11.43 and 28.79 depending on the methodology used to assess the benefits).

Finally, there are some actions governments can take in order to drive the cost of deployment down as well as fostering incentives for network deployment. In this vein, governments should seek policies and regulations aiming to improve the market competition, as well fostering incentives to invest in network deployment by the private sector in order to achieve ICT infrastructure objectives by the year 2030. In this sense, institutional and regulatory framework conditions provide fertile ground for ICT infrastructure deployment.

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Annex 1: WSIS 2011 Targets

- Target 1. Connect all villages with ICTs and establish community access points;
- Target 2. Connect all secondary schools and primary schools with ICTs;
- Target 3. Connect all scientific and research centers with ICTs;
- Target 4. Connect all public libraries, museums, post offices and national archives with ICTs;
- Target 5. Connect all health centers and hospitals with ICTs;
- Target 6. Connect all central government departments and establish websites;
- Target 7. Adapt all primary and secondary school curricula to meet the challenges of the information society, taking into account national circumstances;
- Target 8. Ensure that all of the world's population has access to television and radio services;
- Target 9. Encourage the development of content and put in place technical conditions in order to facilitate the presence and use of all world languages on the Internet
- Target 10. Ensure that more than half the world's inhabitants have access to ICTs within their reach and make use of them;
- Proposed Target 11: Connect all businesses with ICTs.

Source: Partnership on Measuring ICT for Development, WSIS (2011)

ANNEX 2: ICT Related Goals in the Suggested Sustainable Development Goals June 2014

Goal 4. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all

4.7 by 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable

4.c by 2030 increase by x% the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially LDCs and SIDS mechanism for LDCs by 2017, and enhance the use of enabling technologies in particular ICT

Goal 5. Achieve gender equality and empower all women and girls

5.b enhance the use of enabling technologies, in particular ICT, to promote women's empowerment

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

9.1 develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all

9.2 promote inclusive and sustainable industrialization, and by 2030 raise significantly industry's share of employment and GDP in line with national circumstances, and double its share in LDCs

9.4 by 2030 upgrade infrastructure and retrofit industries to make them sustainable, with increased resource use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, all countries taking action in accordance with their respective capabilities

9.5 enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, particularly developing countries, including by 2030 encouraging innovation and increasing the number of R&D workers per one million people by x% and public and private R&D spending

9.a facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, LDCs, LLDCs and SIDS

9.b support domestic technology development, research and innovation in developing countries including by ensuring a conducive policy environment for inter alia industrial diversification and value addition to commodities

9.c significantly increase access to ICT and strive to provide universal and affordable access to internet in LDCs by 2020

Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

Technology

17.6 enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation, and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, particularly at UN level, and through a global technology facilitation mechanism when agreed

17.7 promote development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favorable terms, including on concessional and preferential terms, as mutually agreed

17.8 fully operationalize the Technology Bank and STI (Science, Technology and Innovation) capacity building

ANNEX 3: Compound Average Growth Rate (CAGR) of GDP due to Broadband penetration growth (Formula)

In order to calculate the effect of broadband penetration on total GDP growth (world and developing regions), the following formula is used:

$$CAGB = \left[\frac{\left({PEN_{2030}}/{1-PEN_{2030}}\right) - \left({PEN_{2014}}/{1-PEN_{2014}}\right)}{{PEN_{2030}}/{1-PEN_{2030}}} * \propto +1\right]^{1/16}$$

This formula was used originally used by Roeller and Waverman (2001) as a measure of the annual percent change of fixed telephone penetration multiplied by the estimated penetration coefficient. This formula was adapted from Koutroumpis (2009) for broadband penetration, and it equals to a measure of the compound annual growth effect of broadband on economic growth. The parameter $\propto$ is the elasticity of the impact of broadband penetration on economic growth derived from the simultaneous regression equation approach of Koutroumpis (2009).[44]

Figure A1: Compound Annual Growth rate due to increase in broadband penetration, by Broadband penetration target

	Percentage of growth rate		
Target 1	0.001065	0.030415	Fixed World
Target 2	0.001056	0.019192	Fixed Developing
Target 3	0.001349	0.038532	Mobile BB World
Target 4	0.001171	0.021289	Mobile BB developing
Target 5*	0.001412	0.040343	Fixed+ mobile World
Target 6*	0.001291	0.023467	Fixed+ mobile developing
Target 7	0.001421	0.040591	Universal fixed
Target 8	0.001416	0.040444	Universal mobile

Note: For targets 5 and 6, it is assumed that 1/3 of the target would be fulfilled with fixed networks and 2/3 with wireless networks.

[44] http://ac.els-cdn.com/S0308596109000767/1-s2.0-S0308596109000767-main.pdf?_tid=04dd9e9c-4332-11e4-843e-00000aacb360&acdnat=1411484464_291de3a2327fe69f40587e6b4adad44d

ANNEX 4: Assumptions for the three different scenarios

The **conservative scenario** assumes a high cost of deployment for both fixed and wireless technologies (i.e. USD 1900 and USD 640 respectively) based on estimates of several studies and on industry report estimates. In addition, total capital expenditures (CAPEX) are assumed uniformly distributed among the years 2015-2030. This means that total CAPEX is divided evenly among the years. To calculate the benefits, a low growth rate of the economy is assumed based on World Bank estimates for the year 2016 (i.e. 2.5% for world growth rate and 4.5% for the developing regions), and the lowest elasticity of the impact of broadband penetration on GDP from Koutroumpis (2009) is taken into account (i.e. 0.008).

The **medium scenario** takes into account slightly lower costs per line for fixed networks and the same cost as the conservative scenario for a wireless line (i.e. USD 1460 per fixed line, and same cost per wireless line as the conservative scenario). A medium growth rate of the economy is assumed (i.e. 3% for the world and 5% for developing regions), and the assumed elasticity is that 1% increase on broadband penetration will impact GDP growth in 0.014% (Koutroumpis 2009 medium elasticity).

The **optimistic scenario** assumes high economy growth rates (i.e. 3.5% for the World and 5.5% for developing regions), low costs of infrastructure deployment (i.e. USD 510 for a wireless line and USD 770 for a fixed line), and a high impact of broadband on GDP (i.e. elasticity of 0.023 from Koutroumpis 2009).

Figure A2: Main Parameters of CBA

Inputs	
Discount Factor (Percent)	0.03
	0.05
	0.088
Elasticity of broadband impact in GDP growth (Percent)	0.023
	0.014
	0.008
	0.025
	0.018
	0.09
	0.15
World GDP 2013 in Millions, (Source: World Bank)	USD 74,899,882
Developing regions GDP in 2013 in Millions, (Source: World Bank)	USD 24,487,857
Population 2030 World millions (Source: UN)	8 218
Population 2030 Developing World millions (Source: UN)	6 952
Average GDP growth world (Source: World Bank, estimates for 2016)	2.5
	3
	3.5
Average GDP growth Developing World (Source: World Bank, estimates for 2016)	4.5
	5
	5.5

This paper was written by Emmanuelle Auriol, Professor at the School of Economics, University of Toulouse and by Alexia Lee González Fanfalone, Doctoral candidate at the School of Economics, University of Toulouse. The project brings together 60 teams of economists with NGOs, international agencies and businesses to identify the targets with the greatest benefit-to-cost ratio for the UN's post-2015 development goals.

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