Broadband Stakeholder Group

A Framework for Evaluating the Value of Next Generation Broadband

A report for the Broadband Stakeholder Group

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Foreword

Kip Meek
Chairman, Broadband Stakeholder Group

Determining the economic and social impact of any particular technology or innovation is difficult. Economic historians still debate the precise impact that canals, railways and electrification had on the development of economies around the world; evidence of the impact of ICT on labour productivity has only started to emerge in hard economic data over the last five years; and the precise impact of the internet over the last ten years is still being explored. So predicting the future economic and social impact of a technology that has yet to be deployed is fraught with challenges.

Nevertheless, that is what we have sought to do in commissioning this report on the economic and social value of next generation broadband. Around the world there is a vibrant and growing debate about the need to accelerate the upgrade of communications networks to meet the needs of modern knowledge economies. Those impatient of the need for hard evidence to emerge through the economic data point to the transformations taking place in the world around them, transformations in the way people work, communicate, and seek entertainment. From these observable changes they extrapolate future trends and conclude that the underlying technologies enabling these innovations must be critical to economic well being in the 21st century. In several countries around the world large-scale investment decisions are being taken by firms and in some cases governments, based on such visions.

This report seeks to bridge that gap between the visionaries and sceptics. It seeks to apply economic rigour to what is in effect an exercise in technology and behavioural futurology. But it does so within certain limits. Those looking for a prediction of the precise value of next generation broadband will be disappointed. Such predictions can be made, but are inevitably balanced on a pyramid of assumptions that make them, in our view, too easy to dispute. Nor does this report list in detail, the myriad potential applications and services that could be delivered via next generation broadband. Similar attempts in the past have tended to exaggerate the benefits of services that could be predicted on the basis of current knowledge whilst it was often the changes that were unforeseen, that went on to have the most impact.

What this report does seek to do is set out a framework for understanding where costs and benefits related to the deployment of next generation broadband might accrue across the economy and society, and suggest how these should be accounted for in a cost benefit analysis. It does this against a counterfactual based on our best understanding of the capabilities of existing technologies and likely commercial developments. Categories of cost and benefit are described in generic terms, rather than as precise applications or services.

The methodology underpinning this research has been developed with input from economists in government, academia and business. Inevitably, the authors have had to make many assumptions about technology choices, commercial decisions and policy options. Where assumptions are made, they have been clearly sign posted. The report stresses that they have been made for the purpose of modelling, and that no further significance should be drawn from their inclusion.

Having set the appropriate and necessary cautionary warnings about how the report should be read, it is possible to draw a number of conclusions:

- Having developed a cost benefit framework and looked at some early indicators of value, it is apparent there is likely to be significant social and economic value from the deployment of next generation broadband. It is difficult to predict reliably either the scale or timing of these benefits at this stage. However, the report suggests that although benefits will take time to accrue, there may ultimately be more private value than was indicated in the BSG's Pipe Dreams report published in April 2007. If this is the case, and if the benefits clearly exceeded the costs, it might suggest that, absent other issues, the private sector should be investing. The fact that it is not doing so (or doing so only to a limited degree at this stage) reflects current investor uncertainty over the scale of private value and over their ability to realise enough of that value through new business models or increased consumer willingness to pay, to warrant investment. The level of commercial uncertainty should decline over time, as supply and demand side issues are resolved.
- Regarding the wider economic and social value of next generation broadband the report suggests that, although difficult to quantify, this could be considerable. It is possible to identify a range of wider economic benefits that would accrue in the long term, including reducing costs of transport congestion; enabling virtual agglomeration, by which we mean achieving the productivity benefits of cities and clusters without the need for people to be physically located in such places; improved economic adaptability and resilience, based upon the increased substitution possibilities opened up by improved communications services. In terms of social value, there may be real benefits in terms of improved access to lifelong learning; social inclusion; more flexible working and enhanced social capital. Some of these wider economic and social benefits could eventually be internalised in private value (reflected in willingness to pay by consumers, business or the public sector) however most will take time to accrue and the scale of benefit (or cost) will often depend on a wider set of policy options and choices.
- Regarding the timing of deployment, the report suggests that, in the short term, there are unlikely to be significant costs associated with delayed deployment and that there may actually be significant value in waiting. Economists call this 'option value' and what they mean is that there is much that we can learn about technology choices, deployment techniques, commercial models and policy and regulatory frameworks from what happens in other markets, that will help to ensure that when investment is made in the UK it is done so efficiently. However it should be noted that waiting does not imply doing nothing and there could be significant costs if deployment was delayed in the long-term (5-10 years) and takes place significantly later than in other countries.
- The report then goes on to suggest that when deployment does take place, it would be advisable if this is done as efficiently as possible, making the best use of the resources available and minimising disruption associated with the transition. Since next generation broadband access requires significant investment it is likely to only become available progressively, leading to an uneven distribution of broadband capability across the country. Given our conclusions on benefits, this uneven distribution could have a negative impact if it became persistent. We explore this issue further in a report we have published along side this one called "Models for efficient and effective public-sector interventions in next-generation broadband deployment".

- Finally the report suggests that creating the right enabling environment will be important for ensuring the most efficient use of resources and mitigating potential costs associated with the transition to next generation broadband. The report sets out a number of areas where policy agendas could impact on this.

It was never our ambition, in commissioning this report to provide a definitive answer to the value of next generation broadband. It is quite possible that economists and historians will continue to debate this issue for years ahead. What we have sought to do is set out a framework for understanding the question by categorising the various costs and benefits and suggesting how these should be accounted for in a rigorous cost benefit analysis.

We hope this report will prove useful as stakeholders consider the commercial, regulatory and policy choices ahead and that others may build on this framework as more evidence emerges of the economic and social impact of next generation broadband networks.

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Executive Summary

> *"The difficulty lies, not in the new ideas, but in escaping the old ones."*
> John Maynard Keynes

The report "Pipe Dreams?" published in 2007 by the Broadband Stakeholder Group (BSG) contained nine recommendations including a recommendation calling for further research to understand the potential economic value of next generation broadband to the UK. This study carries that recommendation forward, with the primary aim of developing a framework for considering the incremental costs and benefits of next generation broadband compared to current generation broadband.

We first developed the framework for evaluation. We then developed the scenarios upon which we would base our calculation of incremental costs and benefits. This included developing the counterfactual scenario that sees a continued evolution of current fixed and wireless technologies and other developments that would allow for improved service delivery on the current network, such as improvements in compression technologies, without an investment in next generation broadband. Our next task was to populate the framework with available data, or to provide indications of the scale of the value where data was limited. We provide no estimate of the overall net present value (NPV), as we believe this would be misleading and unhelpful, due to the immature evidence base. Instead, we discuss the scale of incremental value and indicative timescales over which the values would accrue.

In terms of the primary focus of the study, namely developing a framework for considering costs and benefits, we consider that our conclusions are likely to be relatively non-controversial – at least amongst economists. Our categorisation of costs and benefits amongst different categories – wider social, wider economic and private – does however differ from some other studies in that we ascribe relatively more costs and benefits to the category private (in particular some of the potential benefit related to government services). We also set out a range of impacts that we treat as wider economic that some studies might treat as wider social.

The estimation of costs and benefits is necessarily more uncertain and more likely to be controversial. First, our study differs from some others in that we attempt to ascribe benefits to next generation broadband where the characteristics of next generation broadband are necessary to achieving such benefits (a number of other studies consider the total benefits of broadband – current or next generation – whereas we focus on incremental benefits).

However, some of the benefits that we attribute to next generation broadband may be released via development under the counterfactual, including upgrades to copper, cable, and wireless access and other technologies such as compression. It is difficult to quantify the precise incremental benefits of next generation broadband given uncertainty over developments under the counterfactual. Although, we note that many of the longer term benefits of next generation broadband depend on high and consistent speed in both directions – an attribute that is only likely to be available to a limited extent under the counterfactual.

In relation to wider social costs and benefits the challenge is even greater. It may be difficult to judge whether on balance next generation broadband would involve a cost or a benefit. We also know that new technologies typically have unanticipated and unintended consequences, and that when these are negative individuals and society seek to adapt and minimise any harm. As Anderson and Stoneman (2007) put it:

> *"...impacts may be 'bad' (internet steals social time) or 'good' (email generates new social connections) and much time and energy has been wasted debating whether bad predominates over good, whether utopia predominates over dystopia. All of this misses the point... technology does not and has never had a simple linear predictable impact on society."*

Context

It was once remarked that ICT is everywhere but in the productivity statistics. However, post 2000 evidence points clearly to a strong contribution of ICT to overall productivity and GDP growth in some economies. The UK is among these countries, indicating that the UK economy has a demonstrated capacity to utilise ICT productively. Whilst connectivity has contributed to the impact of ICT on productivity growth, widespread broadband availability is too recent to show up in the ICT productivity statistics.

It is clear, however, that broadband is having a large impact on how people work and live. The UK has seen rapid growth in broadband take up with 57 per cent of households having broadband by December 2007. Broadband has transformed the way we use the internet and the services available over the internet. UK consumers have embraced the internet with, by international standards, high levels of time spent online, high levels of use of online services and social websites, and a well developed online market place with high and growing levels of spending online. Next generation broadband would extend the capability of broadband and offer scope for new services and applications.

Cost benefit framework

In developing our analytical framework we distinguish between private, wider economic and wider social costs and benefits. In general, we have treated a wider set of benefits as private than some other studies, including the BSG study "Pipe dreams?" published in February 2007. In particular, we treat many of the potential benefits in terms of government services as private, given that the services are provided by purchasing agents charged with delivering value who can trade-off next generation broadband against other inputs.

Within our broad categories – private, wider economic and wider social – we have sought to identify generic "buckets" where costs and benefits might arise – irrespective of whether we are able to populate each of the categories and estimate costs and benefits.

We also developed a view regarding categories of costs and benefits that should not be included in the framework because they are not relevant or because they are already accounted for elsewhere. We define and discuss these pseudo costs and benefits and include them in the following table summarising our categories.

Finally, we consider separately some distributional impacts across different groups, for example, by income, age, location and disability.

Overview of framework for considering costs and benefits

Private	Wider economic	Wider social	Pseudo – not counted
Private costs are the resource costs of next generation broadband valued in the market Private benefits include: (i) Saving time doing what one would do anyway (ii) Doing more of existing things (iii) New things and transformations	Non-appropriable private Externality Piracy Network effects Spill-over and virtual agglomeration Competition in telecoms sector and wider economy Resilience, adaptability and policy options Excess burden of taxation	Educated citizens Informed democracy and freedom of expression Cultural understanding Belonging to a community and inclusion Privacy Social capital, resilience and trust	Pseudo externalities Asset price changes (if already captured under private cost-benefit) Employment effects "Competitiveness"

Private costs and benefits are valued by individuals and the market, and can be expressed in money terms. We include services purchased by the government within this category.

- Private costs of building a next generation broadband network (net of any operating cost savings).
- Saving time refers to doing what one does now online but more efficiently and productively.
- Doing more refers to doing more of things one can do online now, but which may be constrained by bandwidth.
- Doing new things refers to new applications enabled by next generation broadband such as HD 2-way video.

Wider economic costs and benefits involve a divergence between private and economic value to society.

- Non-appropriable private refers to circumstances where potential private resource value cannot be captured by investors i.e. some radio spectrum and land and buildings.
- Piracy refers to illegal copying and distribution of content.
- Network effects refer to the benefits arising from others using an application (Metcalfe's law).
- Spill-over and virtual agglomeration refers to the positive impact of agglomerations on productivity achieved without agglomeration.
- Resilience, adaptability and policy options refer to improved supply chain management, resilience to shocks and enhanced flexibility in terms of policy options.
- Excess burden of taxation refers to the economic costs of raising public finance.

Wider social costs and benefits refer to social impacts. These categories are reasonably self explanatory and involve wider citizen costs and benefits not captured under the categories private and wider economic.

Pseudo costs and benefits include considerations that should not typically be counted as costs or benefits since they are either irrelevant or should have been counted elsewhere.

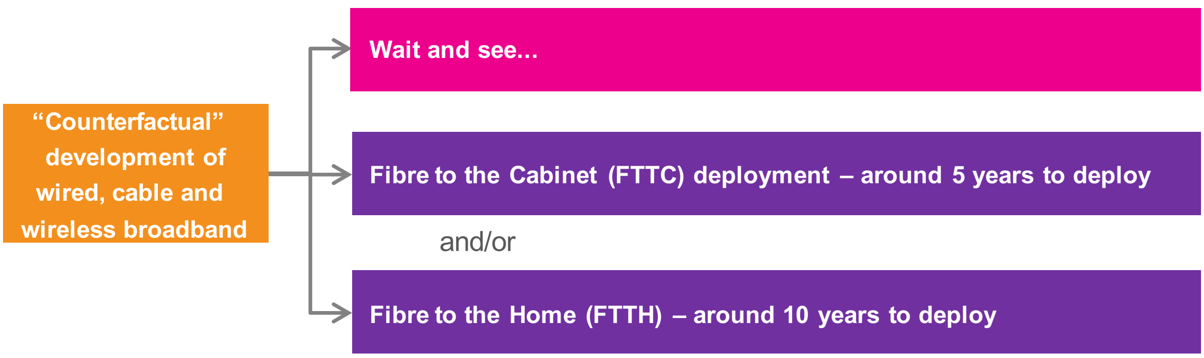
- Pseudo externalities that involve second round impacts mediated within markets that should not be counted.
- Asset price changes that typically reflect flows of costs and benefits that should not be double counted.
- Employment effects generally involve a reallocation of jobs with no net impact.
- "Competitiveness" overlaps with productivity, which is reflected in private and wider economic benefits.

To bring the framework to life we have estimated values for some costs and benefits, and developed a qualitative view of their probable magnitude for others. However, in order to do this we needed to develop a clear view of the capability of a next generation broadband network relative to existing networks, taking account of their likely future evolution. The reason for this is that we are not interested in the value of next generation broadband in this study; rather we are interested in the incremental value compared to what would otherwise be available.

Scenarios

In considering the value of next generation broadband we consider the incremental value of wide spread availability and take-up of next generation broadband against a counterfactual that includes the evolution of existing platforms with upgrades to existing copper, cable (with DOCSIS 3.0) and wireless networks; and no wide area fibre beyond new build (beginning with the Ebbsfleet development in Kent in Autumn 2008).

Timing is explicitly considered since the option to invest in next generation broadband now or in the future exists. In terms of next generation broadband options, we consider the option to wait and see (and potentially invest at some point in future), and the option to invest in the extension of fibre optics closer to, or all the way to the customer premise in the near term. We consider Fibre to the Cabinet (FTTC) where fibre is taken to a street cabinet and existing copper used for the final connection to premises, and Fibre to the Home (FTTH) where fibre is taken all the way to the premise where optical signals are converted to electrical ones. These options are not necessarily mutually exclusive, and are included to give a feel for the range of potential performance and cost involved.



We assume availability to 80 per cent of the population of the UK, corresponding to towns and cities, in our fibre scenarios. Beyond this level of coverage costs are likely to rise significantly and commercial rollout is less likely to be feasible in the foreseeable future. We discuss the question of whether further rollout would bring additional benefits following our assessment of costs and benefits for the 80 per cent availability scenario. We also assume rollout of FTTC over 5 years and FTTH over 10 years or more.

In order to consider the incremental value of fibre we need a clear view of the capability of fibre versus alternatives. The copper telephony network offers wide area broadband coverage, and we therefore focus on the likely evolution of this network. By 2009-10 copper will offer line speeds for the whole of the UK as follows (note that a file size expressed in Megabytes (MB) needs to be multiplied by 8 to convert it to Megabits to be directly comparable with the Megabit per second (Mbps) speeds reported below):

- A maximum access line speed of 0.8 Mbps upstream and 24 Mbps downstream
- A median speed – for 50 per cent of users – of 0.7 Mbps upstream and 9-10 Mbps downstream
- A minimum speed available to 90 per cent of users of 2.5 Mbps downstream

Access line speeds over existing line lengths might improve further in future, though there are constraints in terms of the underlying physics on what can be achieved. Ofcom research published in May 2008 concluded that much higher speeds could in theory be achieved over short lines, whilst theoretically achievable data rates over longer lines are not much higher than those currently available. In terms of the service available to the majority of customers only limited further improvements can therefore be anticipated over existing line lengths.

We also consider cable, wireless and satellite platforms – all of which will see enhanced capability in the near term. We note that some consumers may opt for wireless only access in future – whether or not next generation broadband is available. However, overall we view next generation broadband and wireless access as complementary, with next generation broadband potentially being complemented by a “short tail” wireless network supporting high data rates and levels of use.

The performance of FTTC would be intermediate between copper and fibre all the way to the premise. A preliminary estimate is that FTTC might offer a median upstream speed of around 10 Mbps and a median download speed of 22-30 Mbps. Openreach is carrying out trials and modelling work to refine estimates of the likely capability of FTTC in the UK.

FTTH offers a capability that is consistent, and utilising current Gigabit Passive Optical Network (GPON) technology with typical architectures can deliver uncontended bandwidth of 37.5 Mbps upstream and 75 Mbps downstream (additional bandwidth is available for television services on a separate optical channel over a single GPON fibre). GPON will also allow substantial increases in bandwidth in future. Fibre also has other characteristics such as a low error rate and improved reliability.

Costs

We note that as part of the Government review of barriers to next generation broadband the Broadband Stakeholder Group is undertaking further research on the costs of deployment of FTTH and FTTC in the UK to be published in Q3, 2008.

Our cost assumptions are derived from US estimates and are therefore largely indicative. Further, in practice a range of different technologies might be deployed. For a mix of FTTC and FTTH costs are in the range £5 to £16 billion for 80 per cent coverage, with all FTTC and all FTTH deployments (with 100 per cent take-up) representing the lower and upper ends of this range. Experience of extensive deployment of either technology remains limited and even this broad range of costs may not bracket likely deployment costs.

The costs of FTTH depend on take-up, since connection costs are substantial, for example, overall costs for 50 per cent take-up are estimated at £12 billion. We note that fibre deployment costs have fallen in the US and are anticipated to fall further in future.

We consider one other possibility that in our view deserves further scrutiny, namely a fibre replacement strategy whereby the copper network would be replaced on a location by location basis and all households would be connected to fibre, even those who only wanted to continue with a basic telephone and/or broadband service. The downside of this approach is the cost and disruption involved in connecting all households. The upside flows from the cost savings from running one rather than two networks; the value of copper, land and buildings tied up in copper network that would be released; and the low future migration costs for customers adopting FTTH.

We estimate that if cost savings in the range 30-50 per cent of those involved in operating the copper network could be achieved relatively quickly (including allowance for the value of copper, land and buildings released), then the net lifecycle costs of an FTTH network might be reduced considerably, perhaps down to £9-£12 billion. The incremental operating costs of fibre under a copper replacement strategy are taken into account in the savings assumption of 30-50 per cent with copper replacement (otherwise the saving would be 100 per cent). The costs involved in achieving the shutdown of copper are not included, for example, informing people and migrating non-telephony services dependent on the copper network such as traffic lights. However, overall savings, including proceeds from the sale of copper and land and buildings, could potentially be greater than the above assumptions and net lifecycle costs correspondingly lower.

Other costs we have not quantified include core network enhancement costs to accommodate additional traffic generated by next generation broadband, and any overall change in operating costs associated with FTTC or FTTH overlay. Any change in operating costs would depend on the details of deployment, for example, whether local exchanges are maintained under FTTC or whether copper lines are maintained for those who opt for FTTH.

Wider economic and social costs including greenhouse gas emissions and road traffic congestion are considered under benefits, since there are both potential costs and benefits in these areas.

Benefits

Our assessment of costs considered potential benefits in terms of operating cost savings and the release of copper, land and buildings. Here we focus on the value of applications that next generation broadband would enable. In assigning value to applications we assume an FTTH deployment – FTTC would offer lower capability, and therefore lower value, at lower cost.

Focusing on private benefits we note first that these would arise along extended value chains, and not all the value would be captured by consumers or investors in next generation broadband. We consider three categories of benefits – doing what people do now more productively (the value of time savings), doing more utilising existing applications, and doing new things and transformations.

The first of these categories of private benefits is potentially very large given the amount of time people spend online and would occur in the short term. However, we found very limited information on precisely how people spend their time online, and simply assumed that 50 per cent of users save 3 per cent of their time online. This would generate a benefit of almost £1 billion per annum.

The next category – an expansion of existing things people do – was even harder to value. Yet it seems clear to us that this category would be large if constraints on uploading and two way services were substantially reduced.

The final category of private benefit – new things – is impossible to fully anticipate. In terms of potential transformations, two stand out. First, HD video distribution and two-way HD video communication. Second, a progressive move to "cloud" computing involving storage, computation and software applications available over the internet. Whilst the value of these transformations is potentially large, they would take some time to reach their potential.

In relation to wider economic costs and benefits, we considered a range of impacts including externalities such as traffic congestion and greenhouse gas emissions, spill-over virtual agglomeration benefits, competition and economic resilience, adaptability and policy options.

Gains in spectrum efficiency could flow from the substitution of local within building transmitters and next generation broadband connections for higher cost spectrum and base stations (a private benefit); and/or the substitution of fibre carriage for terrestrial broadcasting with an accompanying release of UHF spectrum (a wider social benefit since UHF spectrum is non-tradable). The value of spectrum efficiency gains is potentially large, though such gains might only be realised in the medium to long term.

In terms of "externalities" we considered road traffic congestion and greenhouse gas emissions (during and following network build). Overall the impact in terms of these externalities is unclear. However, if flexible economic instruments are in place to internalise such externalities, then next generation broadband could reduce the cost of reducing congestion and greenhouse gas emissions.

Three categories of potential wider economic benefit that we did not quantify appear particularly important, namely spill-over and agglomeration benefits, competition (both in the telecoms sector and more widely) and economic resilience. The first of these refers to the potential for next generation broadband to partially substitute for proximity and local network effects – thereby potentially achieving the productivity benefits of cities and clusters without the need to get more people to live and work in them.

The second reflects the scope for next generation broadband to expand trade in services, and therefore to increase the overall level of competition and innovation in the economy. Labour market search and matching might also be made more efficient via next generation broadband. We note that work is underway to maintain competition in the telecoms market during the transition to next generation broadband – including non-discrimination (equivalence) requirements.

The third reflects the fact that ICT is thought to have contributed to increased economic resilience via improved supply chain management. Next generation broadband might deepen this benefit and would open up new substitution possibilities within the economy, thereby increasing resilience to shocks (such as an oil price shock). Greater flexibility may expand the set of feasible policy options.

In relation to wider social costs and benefits we considered educated citizens, informed democracy and freedom of expression, cultural understanding, belonging to a community and inclusion, privacy and social capital, resilience and trust. Whilst next generation broadband, like any other technology, is likely to generate positive and negative wider social impacts, we concluded that there would be a number of positive impacts and few negative impacts.

The scope to improve access and inclusion for those with limited mobility or disability, to improve lifetime learning and to increase overall social resilience stood out in terms of potential positive impacts. Whilst some of these benefits are private to the individual they also involve wider benefits to society. The following box provides examples of such benefits.

Illustrative examples of wider social benefits in relation to government services

The OECD (May 2008) refer to a range of potential benefits in relation to the application of advanced broadband in health, care of the aged and disabled and education. However, the studies the OECD draw on do not attribute benefits to different forms of broadband including wireless, current and next generation broadband. Our focus is on the narrower question of the potential incremental benefits of next generation broadband.

An illustration of the constraint where bandwidth is shared is provided by schools where it may be desirable for a whole classroom of 30 children to view video simultaneously. At present this might be achieved using a single PC and projection system. However, to enable individual class members to experience a satisfactory interaction with visual material online a high connection speed for the classroom or school as a whole is required. High bandwidth not only enables individual interaction, but also reduces the likelihood of download delays leading to classroom disruption. An illustration of the difference a high speed connection can make is provided by experience in Scotland where high speed connections have been provided to a number of schools using fibre.

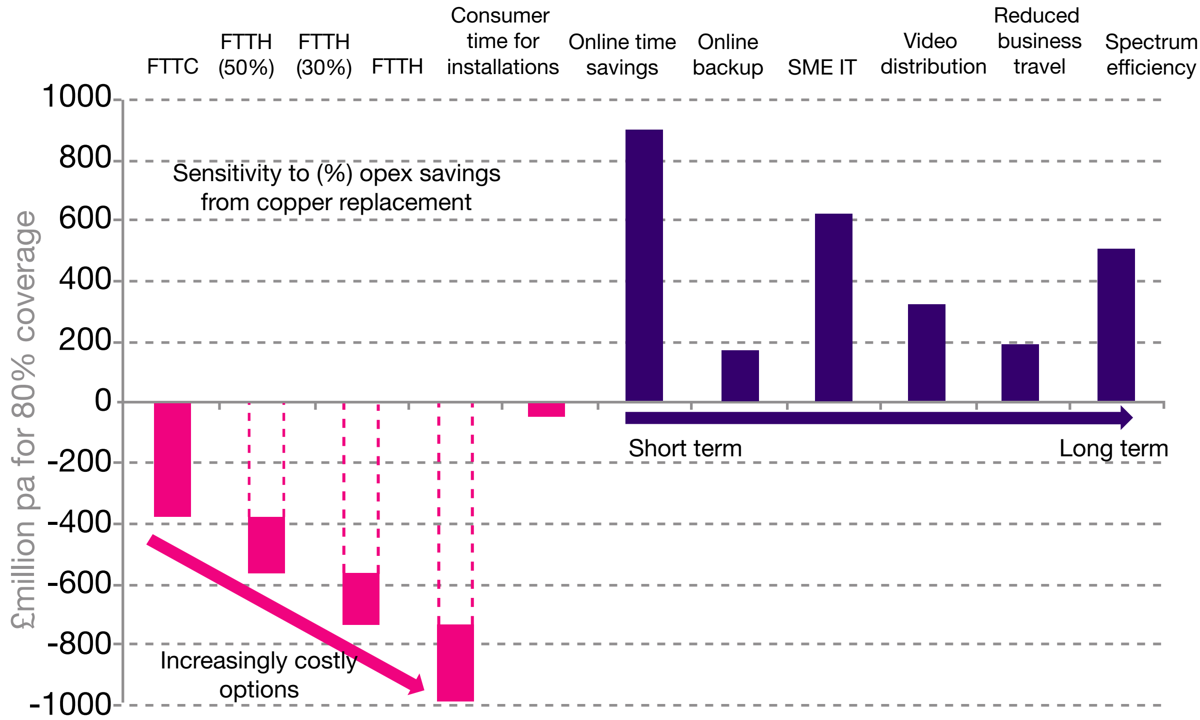
In the health sector, improved connectivity could lower service delivery costs and improve service via e-health and telemedicine. The European Union currently sponsors more than 50 e-health projects under the 6th Framework Programme. A number of applications in relation to patient monitoring may involve relatively modest rates of data transfer, and may be best suited to wireless connectivity. Other applications may require very high bandwidth and reliability/quality of service – potentially beyond the capability of wide area fibre networks and best suited to dedicated point to point deployments. However, a range of current and potential applications would benefit from wider availability of next generation broadband including virtual face-to-face consultations for patients and caregivers. Next generation broadband may also facilitate social distancing and improved management of pandemics.

Overall, we consider that there are likely to be substantial benefits associated with next generation broadband in the medium term. We note however that some constraints on the realisation of value may be unavoidable, or slow transformation down as new opportunities are explored and new relationships in the value chain are negotiated. Others could be eliminated or minimised via the development of appropriate policy and regulatory frameworks in relation to next generation broadband investment and related elements of the value chain. Doing so should be a priority since the decisions that must be taken are long term ones, planning may start early and inefficient plans and decisions might otherwise be developed and taken.

On the next page we summarise the costs and benefits we have quantified alongside a qualitative assessment of categories of costs and benefits we have not quantified. The graph and table should be interpreted together. In interpreting this information it is important to note that:

- The investment costs shown are for alternatives and a single investment option (in magenta) and should be compared with other costs and benefits (in purple).
- Lump sum costs and benefits (investment costs, consumer time for installation and spectrum efficiency) were converted to equivalent annual flows to allow comparison with other benefits.
- Costs and benefits arise at different times with the short term towards the left and the long term towards the right of the chart.
- All benefits are estimated assuming FTTH. Whilst the benefits with FTTC would be smaller we have not estimated by how much since the UK capability of FTTC is currently unknown.
- Whilst the qualitative benefit-cost appraisal is not intended to be precise (+++) could be thought of as of similar importance to the larger bars on the chart.

Indicative incremental annual costs and benefits



Qualitative assessment of other incremental benefits (+) and costs (-)

Scale	Private	Wider economic	Wider social
(+++)	Un-quantified increase in existing activity Un-quantified new things	Resilience, adaptability and policy options Spill-over and virtual agglomeration benefits	Social capital, resilience and trust
(++)		Competition in wider economy	Educated citizens Belonging to a community
(+)		Value of leased exchange land and buildings Reduced traffic congestion Network effects	Informed democracy
Neutral-unclear		Piracy Competition in telecoms Greenhouse gas emissions	Cultural understanding Privacy
(-)	Core network enhancement Costs of transition from copper to fibre with copper replacement Any change in operating costs associated with FTTC or FTTH overlay	Traffic congestion and other disamenity during fibre build Excess burden of taxation for public funding	

Incremental impact of different levels of coverage

We assume 80 per cent coverage in our scenario. This is approximately the proportion of UK households located in towns and cities and also roughly corresponds with the footprint of unbundled local telephone exchanges in the UK. An important question is what costs and benefits might arise with more, or potentially less, coverage.

In terms of private costs, our understanding is that these increase significantly for an extension of next generation broadband beyond towns and cities (i.e. beyond 80 per cent coverage). However, the costs of network extension may fall if costs of next generation broadband fall and long reach fibre become feasible. Willingness to pay may also grow as incomes rise and new applications are developed, improving the commercial case for extension.

During the transition to next generation broadband some communities will necessarily gain access to the service before others. This will result in relative disadvantage for most communities initially. However, communities and individuals that remain beyond the reach of commercial deployment in the long-term would be disadvantaged, to the extent that next generation broadband has incremental value.

Experience from first generation broadband suggests that geographic inequalities will become a significant issue. At some point, if next generation broadband is delivering significant benefits to users, it is likely that the costs and benefits of extending coverage beyond commercial rollout will need to be addressed.

Incremental benefits of FTTH over FTTC

FTTC could in principal deliver sufficient bandwidth to support many applications. However, given that we do not currently have good estimates of the likely capability of an FTTC deployment in terms of bandwidth (up and down), consistency and reliability for the UK, the incremental benefits of FTTH over FTTC are difficult to judge.

Some applications, and in particular the capability to run a number of applications simultaneously, may be unique to FTTH. Further, the high degree of assurance in relation to performance provided by FTTH means that the scope to credibly offer differentiated service packages with different bandwidths and to market them may be greater, thereby increasing private investor benefits for a given level of willingness to pay.

Late versus early deployment

The option to wait exists alongside the option to invest now. Waiting may be valuable if net benefits are expected to rise over time or if some existing uncertainties over costs and benefits might be resolved – which might then lead to a decision to invest or wait longer. Therefore, the investment decision rule is not whether the net present value is greater than zero, but whether it is greater than the value of waiting. This also leads us to reframe the question “what is the cost of delay?”, as the value of delay may be positive in the short term even if the expected value of the investment is positive.

We consider that there is a large option value (i.e. benefit) attached to waiting over the short term. In the medium term, this (option) value might decline as constraints on realising value are removed and as some existing uncertainty over costs and benefits is resolved. In relation to the question regarding the costs of delay, our analysis points to the possibility that delay would be beneficial in short term and costly in the medium to long term. Further, we conclude that investing now simply because some others are would not be sensible. The case for investment should be evaluated independent of whether others are investing or not, but should of course draw on their experience.

Further potential work on the value of next generation broadband

Our analysis raises a number of issues in relation to the costs and benefits, and potential barriers to the realisation of value, in relation to next generation broadband. In particular:

1. Realising the full value of next generation broadband depends on the extent of transformation of other markets. In considering the private and wider value of next generation broadband, and potential regulatory and public policy barriers to next generation broadband, other platforms and markets should be considered including spectrum, broadcasting, mobile and copper networks. In particular, the costs and benefits of copper network retirement alongside fibre rollout, and the policy and regulatory environment required, should be considered.
2. Costs and benefits in terms of consumer convenience and the value of individuals' time should be considered in assessing ways in which government services might be enhanced via next generation broadband.
3. The linkages between transport and communications as enablers of economic development, and the role of communications technology as a complement and substitute for transport (via home working, telepresence and collaboration tools) should be explored with a focus on virtual agglomeration benefits. This could be integrated with follow up work to The Eddington Transport Study by the Department for Transport.
4. The scope for next generation broadband to mitigate (via "social distance") and help manage a pandemic via information and remote consultations could be explored.
5. The anticipated capability of FTTC, and the uncertainty surrounding it, should be evaluated.
6. Research could be focused on better understanding how people use the internet, their allocation of time across activities including waiting and how their behaviour may be constrained by currently available bandwidth.

1 Introduction

"…there would seem to be something in the Scandinavian blood...which renders the possession of many telephones an essential to their owners' happiness. Wherever two or three Swedes, or Norwegians, or Danes, or Finns of Scandinavian descent, are gathered together, they almost infallibly proceed to immediately establish a church, a school, and a telephone exchange. Whatever else in life that is worth having generally comes after."
Bennett (1895)[1]

In this section we set out the terms of reference for this study and highlight a number of recent government policy documents relevant to its remit. We then introduce the challenges of addressing the terms of reference and the approach we have taken. Finally we explain the structure of the rest of the report.

1.1 Terms of reference

The report "Pipe Dreams?" published by the Broadband Stakeholder Group (BSG) contained nine recommendations including a recommendation calling for further research to understand the potential economic value of next generation broadband to the UK.

The BSG commissioned Plum to implement this recommendation with the objectives of:

a) Creating a conceptual framework for understanding the potential economic and social value that could accrue from the widespread availability and take-up of next generation broadband services and the social and economic shortfall that might result from late deployment or incomplete coverage or adoption.

b) Creating an estimate of the potential scale of the value or the cost of late deployment or incomplete coverage.

1.2 Related government policy documents

Subsequent to commencement of the study a number of further announcements have focused on next generation broadband, and provide a wider context for consideration of the issue.

- The BERR publication "Globalisation and the changing UK economy" referred to the role of ICT in greatly raising the tradability of goods and services.[2]
- The February 2008 DCMS paper "Creative Britain – New Talents for the New Economy" included the following commitment: "The Government will review what the barriers to investment in next generation broadband may be."[3]

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[1] Cited in Scott Wallsten. March 2003. "Returning to Victorian Competition, Ownership, and Regulation: An Empirical study of European Telecommunications at the Turn of the 20th Century." http://www.wallsten.net/papers/wallsten_europe_telhist.pdf

[2] BERR. February 2008. "Globalisation and the changing UK Economy." http://www.berr.gov.uk/files/file44332.pdf

[3] DCMS. 22 February 2008. "Creative Britain – New Talents for the New Economy." http://www.culture.gov.uk/NR/rdonlyres/096CB847-5E32-4435-9C52-C4D293CDECFD/0/CEPFeb2008.pdf

- The March 2008 Budget update of the long term opportunities and challenges document refers to the role of ICT and communications infrastructure in the economy in lowering transaction costs, promoting the diffusion of knowledge and allowing specialisation in production and greater trade in goods and services.[4]

This report should be considered within the context of these developments, and will provide an input to the Government commissioned review of barriers to investment in next generation broadband.

1.3 Our approach

The terms of reference asked three specific questions of this report: firstly, to develop a conceptual framework for understanding the incremental value of next generation broadband; secondly, to assess the social and economic shortfall that might result from late deployment or incomplete coverage or adoption; and thirdly to create an estimate of the potential scale of the relevant costs and benefits.

Our approach has been designed to ensure that the framework created is as robust as possible. We have consulted widely during the creation of the framework with industry, government, the regulator and academics, as well as reviewing available studies on the value of broadband.

We then developed the scenarios upon which we base our calculation of the benefits. This included developing the counterfactual scenario that sees a continued evolution of current fixed and wireless technologies and other developments that would allow for improved service delivery on the current network, such as improvements in compression technologies, without an investment in next generation broadband. Our next task was to populate the framework with available data, or to provide indications of the scale of the value where data was limited.

We provide no estimate of the overall net present value (NPV), as we believe this would be misleading and unhelpful, due to the immature evidence base. Instead, we discuss the scale of incremental value, indicative timescales over which the values would accrue and provide recommendations for further work to add to and build on the estimations made.

1.4 Challenges

In terms of the primary focus of the study, namely developing a framework for considering costs and benefits, we consider that our conclusions are likely to be relatively non-controversial – at least amongst economists. Our categorisation of costs and benefits amongst different categories – wider social, wider economic and private – does however differ from some other studies in that we ascribe relatively more costs and benefits to the category private (in particular some of the potential benefit related to government services). We also set out a range of impacts that we treat as wider economic that some studies might treat as wider social. The estimation of costs and benefits is necessarily more uncertain and more likely to be controversial.

In relation to wider social costs and benefits the challenge is even greater. It may be difficult to judge whether on balance next generation broadband would involve a cost or a benefit. We also know that

[4] HM-Treasury. March 2008. "The UK economy: analysis of long-term performance and strategic challenges." http://www.hm-treasury.gov.uk/media/6/2/bud08_strategicchallenges_645.pdf

new technologies typically have unanticipated and unintended consequences, and that when these are negative, individuals and society seek to adapt and minimise any harm. As Anderson and Stoneman (2007) put it:

> *"...impacts may be 'bad' (internet steals social time) or 'good' (email generates new social connections) and much time and energy has been wasted debating whether bad predominates over good, whether utopia predominates over dystopia. All of this misses the point... technology does not and has never had a simple linear predictable impact on society."*

1.5 Report structure

The remainder of the report is set out as follows. We start by examining the background to the issue, reflecting on the importance of ICT, and broadband in particular, to the knowledge economy and society in general. We also consider the challenges created by increased take-up and usage of first generation broadband, and the implications for the current network. We move on to define next generation broadband, and discuss the value attributes that differentiate next generation broadband from first generation broadband.

In Section 3 we present the cost-benefit framework. We define the categories of benefit-cost, explain why these have been chosen, and explain why some benefits should not be counted and how some categories of benefit that are not listed are captured in other categories.

We then describe scenarios for the development of broadband in the UK. Firstly we set out the counterfactual, which describes what we know about future developments. Secondly we describe the option to wait and see. We then describe deployment scenarios for fibre to the cabinet (FTTC) and fibre to the home (FTTH).

Drawing on the framework and scenarios we provide estimates of the costs and benefits. We provide estimates that are indicative of the scale of the value where data is available, and suggest the scale of value where data is not available. The intention is to provide a sense of the magnitude of the main categories of value attributable to next generation broadband.

Finally, we provide a final concluding section that reflects on what the report says about the questions raised by the terms of reference, and provides suggestions for further work that would provide new evidence to populate the framework and facilitate the realisation of value.

2 Background and context

"Super-fast broadband – next generation access and networks – are crucial to the UK's future. These networks form part of the critical infrastructure of the country's economy and will be central to the way we live our lives in the future...it will in time have a similar impact upon our society and economy as we have seen with first generation broadband." Ed Richards, Ofcom Chief Executive. 16 April 2007

2.1 Introduction

In this section we discuss the relationship between ICT and productivity growth and the role of broadband as a key component of ICT. We then go on to discuss the development of broadband over the last eight years and highlight the investment challenge related to access networks. We provide a definition of next generation broadband and set out key incremental value attributes of next generation broadband compared to current generation broadband.

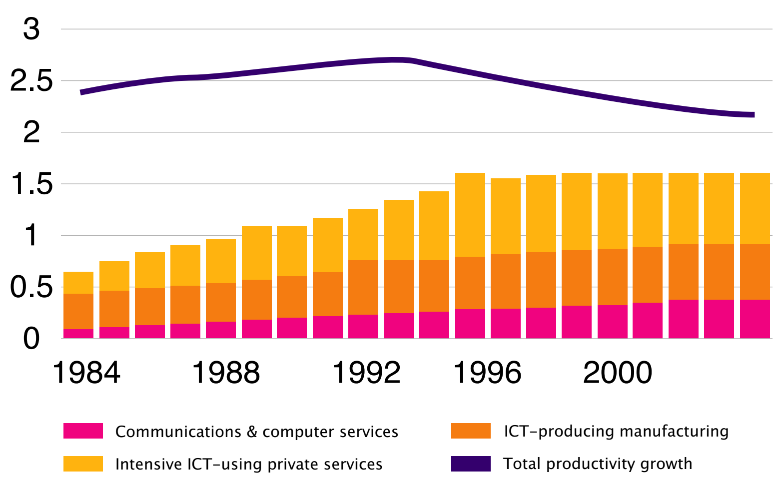
2.2 ICT and productivity growth

It was once remarked that ICT is everywhere but in the productivity statistics. However, post 2000 evidence points clearly to a strong contribution of ICT to overall productivity and GDP growth in some economies. The UK is among these countries, indicating that the UK economy has a demonstrated capacity to utilise ICT productively.

Figure 2-1 shows overall labour productivity growth per hour and ICT component contributions for the UK from 1984-2003 (with smoothed data, the raw data also indicates a similar pattern, though with much more annual variation). The comparisons are based on data from the Groningen Growth and Development Centre, who have normalised national data into a reasonably comparable database.[5]

Figure 2-1

ICT contribution to productivity growth, %pa



[5] Source data from "Groningen Growth and Development Centre, 60-Industry Database", September 2006, http://www.ggdc.net

The contribution of ICT has increased substantially, with all three components: communications and computer services, ICT-producing manufacturing and intensive ICT-using private services increasing.[6] Note that broadband is too recent to have made a significant contribution to productivity growth during the period covered by available data, though business connectivity and the internet are likely to have played an important part.[7]

It is useful at this point to explain the relationship between our framework for analysis and overall outcomes in terms of welfare, GDP and productivity growth. The approach we adopt is to consider economic welfare and to estimate changes in welfare by considering categories of economic impact and possible applications in relation to next generation broadband.

Some studies suggest that productivity and GDP impacts *per se* are externalities. In general they are not. Productivity gains result in higher real earnings and/or profits, whilst GDP is simply productivity per hour worked times hours worked i.e. these macroeconomic measures represent the sum of private behaviour where rewards are to a significant extent internal to individuals. For this reason we have not included productivity and GDP in our framework in addition to the welfare gains we estimate. To do so would be double counting.

Because the number of hours that individuals can, or wish to work, is constrained, the only sustainable source of growth in GDP per capita is productivity growth. In turn, labour productivity growth is driven by the substitution of capital (in the broad sense of physical, human and intellectual capital) for labour to produce a given level of output. Here we can see the link to investment in next generation broadband – provided such investment is an efficient use of resources it will contribute to productivity and GDP growth.

However, in addition to these impacts, next generation broadband would have wider impacts and free up time (since it is faster) which people might utilise in terms of leisure, doing more of what they do now online or doing new things. We value such time savings regardless of how people chose to "spend" them.

2.3 Development of broadband, applications and content

Broadband barely existed in the UK at the time of the dotcom crash in 2000, yet has exhibited the fastest growth of any communications technology with household penetration now over 57 per cent (for the final quarter 2007) and growing[8] (**Figure 2-2** shows penetration on a per capita basis).[9]

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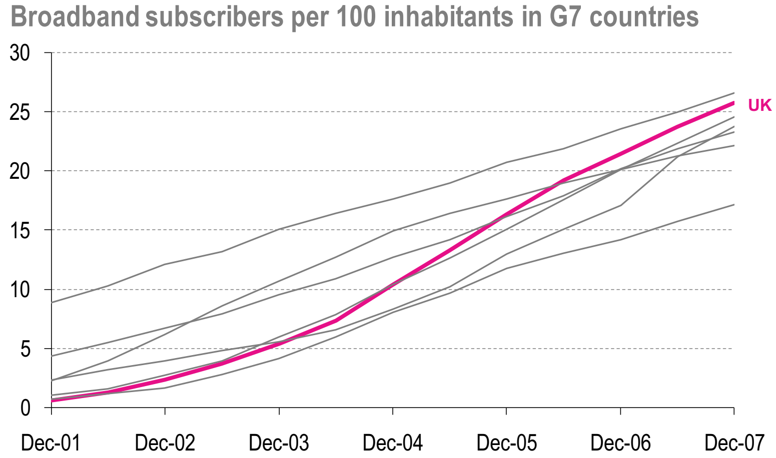
[6] In contrast in the EU-15, overall productivity growth has declined, whilst the contribution of ICT has increased only modestly over the past 25 years. The share of productivity growth that is accounted for by ICT has therefore risen, but overwhelmingly because overall productivity growth has fallen. The decline in overall productivity growth in Europe, which is not obviously ICT related, is discussed in Robert J. Gordon and Ian Dew-Becker. November 2005. "Why Did Europe's Productivity Catch-up Sputter Out? A Tale of Tigers and Tortoises." http://www.frbsf.org/economics/conferences/0511/1_ProductivityCatchup.pdf

[7] Brian Williamson. June 2007. "ICT, connectivity and productivity." In "The Economic Benefits from Providing Businesses with Competitive Electronic Communications Services". Part 2. http://www.btplc.com/Thegroup/Regulatoryinformation/Consultativeresponses/BTdiscussionpapers/Electronic/index.htm

[8] Ofcom. May 2007. "Tomorrow's wireless world." http://www.ofcom.org.uk/research/technology/overview/randd0708/randd0708.pdf

[9] OECD. May 2008. "Broadband statistics." http://www.oecd.org/document/54/0,3343,en_2649_37441_38690102_1_1_1_37441,00.html

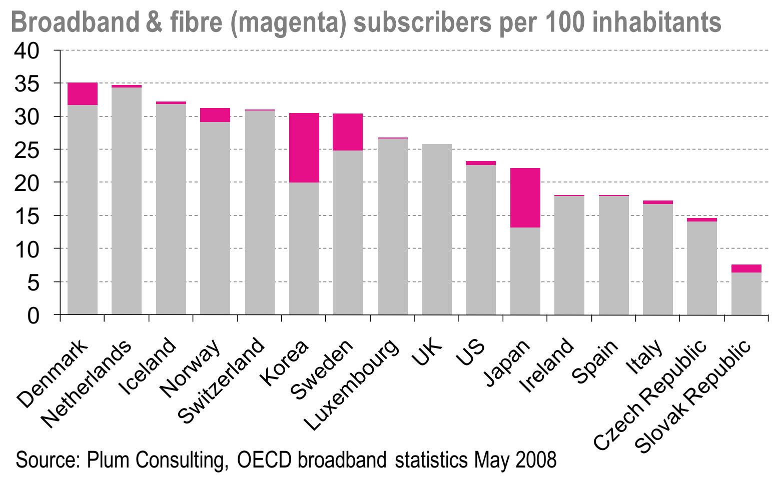
Figure 2-2



Source: Plum Consulting, OECD broadband statistics May 2008

Fibre investment is much less developed and less uniform across countries. Figure 2-3 shows levels of fibre and other broadband penetration for OECD countries with fibre based access including FTTH and fibre to the building (including the UK, which has no wide area fibre at present, for comparative purposes).

Figure 2-3



Source: Plum Consulting, OECD broadband statistics May 2008

OECD evidence also shows that across age, income, education, profession and size of towns the internet shows one of the most rapid declines in inequality of possession over time.[10]

UK consumers are among the most active users of the internet in terms of time online, the share of online shopping as a percentage of retail sales, internet advertising and use of Web 2.0 services. As a nation we have taken to the internet. Box 2-1 illustrates.

[10] OECD. December 2007. "Broadband and ICT access and use by households and individuals." http://www.oecd.org/dataoecd/44/11/39869349.pdf

Box 2-1: UK citizens are very active online by international standards

- The UK has the most active online population in Europe, with the average 15+ user (a population of 31 million users) spending 34.4 hours online per month at home or at work compared to an average of 24 hours in Europe and 31.4 hours in the US.[11]
- The UK is the largest online market in Europe with online sales of £46.6 billion or 15 per cent of overall retail sales in 2007, up 54 per cent on 2006.[12]
- The UK had the highest level and share (14 per cent) of advertising online in 2006 among countries considered in the Ofcom International Communications Market Report 2007 including the US.[13]
- The UK has the most Facebook users outside the US, with 8 million active users.[14]
- Over 42 million programmes have been streamed or downloaded in the three months to March 2008 following the Christmas Day marketing launch of BBC iPlayer.[15] iPlayer availability was extended to the Nintendo Wii in April, and to the Virgin Media cable TV service in May.

Just at the point when broadband has almost replaced narrowband internet access and we are seeing a proliferation of so-called web 2.0 services, next generation broadband technologies offer the prospect of an even better experience of the internet and further innovation in services, applications and use. However, unlike the initial transition to broadband much greater up-front investment is required in cable, fibre-optic and wireless technologies to deliver next generation broadband.

In some countries significant investment in next generation broadband is proceeding, for example, the US, Korea and Japan. However, the right choices in terms of technology, for example whether to run fibre all the way to the customer or to the street or building with copper carrying data the final leg, are uncertain. Mistakes are likely, may already have been made and will prove irreversible in the sense that investment is wasted.

Demand for consistent and higher speeds and higher upstream capacity is growing, as new web 2.0 services, and the uploading and downloading of video in particular increase in usage. To put the timeframes in perspective Flickr photo sharing launched in 2004, YouTube video sharing in 2005, Facebook opened to the public in September 2006, Gmail 2007, BBC iPlayer in December 2007 and Apple TV 'Take Two' in January 2008.

The growth in traffic over the last few years has been dramatic. YouTube currently consumes as much bandwidth as the entire Internet required in 2000. Growth to date has largely been unconstrained by price signals, as broadband operators have tended to offer flat rate unlimited usage packages to consumers. Overall internet traffic is forecast to continue to grow rapidly. Cisco forecast 42 per cent annual growth to 2011 for global consumer traffic (see **Figure 2-4**).[16]

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[11] comScore. June 2007. http://www.comscore.com/press/release.asp?press=1459

[12] IMRG. January 2008. http://www.imrg.org/ItemDetail.aspx?clg=InfoItems&cid=pr&pid=pr_IMRG_Index_Jan08&language=en-GB

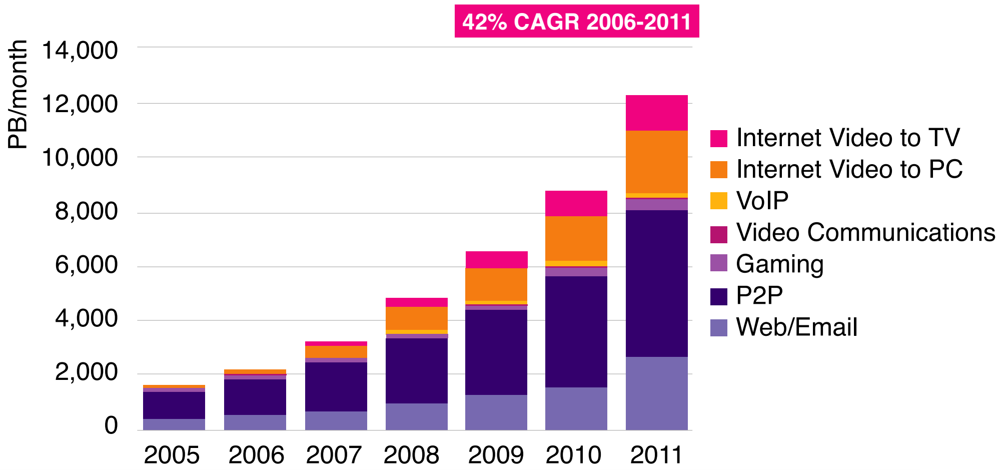
[13] Ofcom. December 2007. International Communications Market Report 2007. Pages 18 and 65. http://www.ofcom.org.uk/research/cm/icmr07/icmr07.pdf

[14] February 2008. http://www.facebook.com/press/info.php?statistics

[15] BBC. 9 April 008. http://www.bbc.co.uk/pressoffice/pressreleases/stories/2008/04_april/09/iplayer.shtml

[16] Cisco. 14 January 2008. "The Exabyte Era." An exabyte is a billion Gigabytes. http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/net_implementation_white_paper0900aecd806a81a7.pdf

Figure 2-4: Cisco global consumer internet traffic forecast



Growing diversity of internet use is also driving greater and simultaneous use within households. Whereas once there might have been a single PC within a household, increasingly bandwidth is shared over wireless networks;[17] with simultaneous use driven by growth in the diversity of devices able to access a broadband/wireless connection including laptops, games consoles, internet tablets and mobile phones such as the iPhone and TVs (currently via a set top box, but in the near future directly).

Without further investment in all parts of the network, the outcome of rapidly increasing traffic growth would be declining effective bandwidth per user and constraints on what people can do. Income growth will also progressively raise the value attached to time savings and high quality broadband service.[18]

The content and applications that could initially drive value from next generation broadband are here now and are evolving rapidly. Operators are also starting to invest in faster access networks. Virgin Media is planning to upgrade the capability of cable starting in 2008 and BT has announced its intention to deploy fibre at the new development at Ebbsfleet in Kent. It is in relation to replacement of legacy copper service that the business case is harder to make.

2.4 Definition of next generation broadband

In defining next generation broadband we do not propose a particular bandwidth threshold, but focus on the step change in performance across a number of attributes that next generation broadband technologies, can deliver. These include greatly improved reliability and consistency of speed across users and time, higher download and upload speeds in particular, and reduced error rates that improve performance of real time applications such as video streaming and video communication in particular.

[17] Within the home, WiFi has grown as a means of connecting to the internet from 1 per cent in 2003 to 29 per cent in 2007. Dutton and Helsper. 2007. "Oxford Internet Survey 2007 Report: The Internet in Britain." Oxford Internet Institute. http://www.oii.ox.ac.uk/research/oxis/OxIS2007_Report.pdf

[18] Real income per capita in the UK will have risen by 37 per cent (over £7,800) by 2025 compared to 2006, assuming historic rates of productivity growth. Williamson, Black and Lay. December 2007 (published May 2008 by Ofcom). "Macro scenarios to 2025." Page 8. http://www.ofcom.org.uk/research/technology/research/sectorstudies/macro2025/macro2025.pdf

Ofcom, in its “The International Communications Market 2007” report, mentions a benchmark threshold of 20 Mbps as significantly in excess of current levels. However, the broadband service (ADSL2+) currently being deployed by a number of broadband operators delivers median speeds of 0.7 Mbps upstream and 9-10 Mbps downstream. ADSL2+ deployment should be complete by 2010 at which time we estimate that 90 per cent of users will get at least 2.5 Mbps downstream.[19]

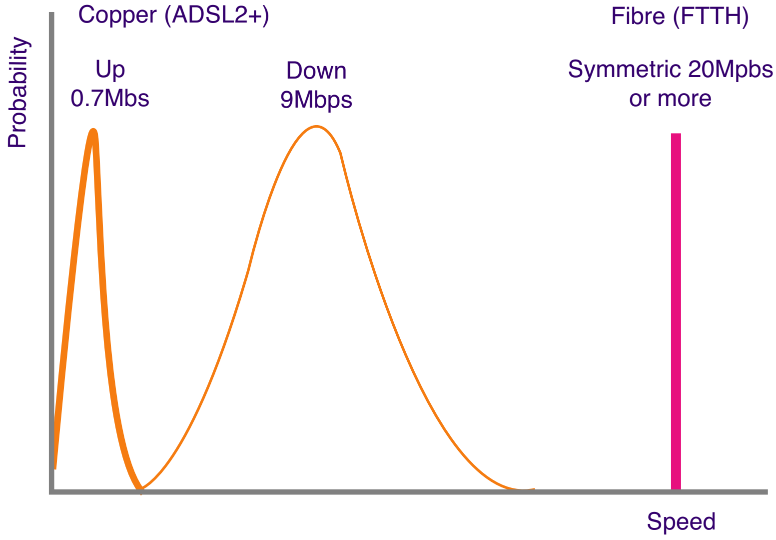
2.5 Value attributes of next generation broadband

The incremental benefits of next generation broadband over the current generation of broadband services ultimately flow from the enhanced user experience and services it can support. These in turn depend on the attributes of next generation broadband:

- Much greater consistency of bandwidth across users and over time.
- Higher download and particularly upload speeds.
- Greater reliability of service i.e. a reduction in faults.
- Other improvements in quality of service including lower latency (lags in responding), lower error rates (which can disrupt streamed video) and freedom from radiofrequency interference (which raises the quality of video applications).

Figure 2-5 illustrates the qualitative difference between the first two of these characteristics for fibre (FTTH) and copper based DSL access. FTTC is intermediate between DSL and FTTH.

Figure 2-5: Attributes of copper DSL and fibre FTTH



Speed is shown on the horizontal axis and probability on the vertical axis. In the left hand of Figure 2-5 the two DSL distributions show the likelihoods of different upload and download speeds across users i.e. there is a wide variation in performance across users and download speeds are considerably greater than upload speeds.

[19] Speeds as low as 3-5 Mbps, consistently delivered in both directions at low error rate might be regarded as next generation broadband under our definition, and are certainly beyond the capability of exchange based ADSL2+.

The right hand side of **Figure 2-5** shows that FTTH offers higher speed in both directions (with the option to upgrade capacity in future). The indicated speed of 20 Mbps or more reflects the highest speed symmetric plan currently offered commercially by Verizon in the US. GPON fibre is capable of higher speeds. Fibre also offers higher reliability, and low error rate – indicated by the solidity of the vertical bar.

Although the characteristics of fibre have no value *per se*, they do greatly improve the user experience and service capability of broadband. Speed saves time and provides more realistic scope for users to share content and interact online, whilst reliability and consistency would allow services currently performed via local area networks to be performed via the core network allowing productivity gains for businesses.

Finally, we note that the very high level of consistency provided by FTTH expands the scope for service and price differentiation, which, in turn, could improve the investment case for a given level of benefit.

3 Cost-Benefit Framework

"The cost of a thing is the amount of what I will call life which is required to be exchanged for it, immediately or in the long run." Henry David Thoreau

3.1 Introduction

In this section we set out the categories of incremental cost and benefit that we believe can and should be included in a cost benefit analysis of the social and economic impact of next generation broadband. We do not attempt to quantify any of these effects in this section – that is done in Section 5. We do however discuss a number of pseudo costs and benefits, which we believe should not be included in the framework.

3.2 Methodology for identifying costs and benefits

Our focus is on net incremental benefits of wide area next generation broadband compared to a counterfactual where there is wide area coverage with broadband (including known plans for upgrading the capabilities of copper, cable and wireless) and point-to-point fibre in relation to high demand/high value sites.

We focus on the welfare of individuals and society, and not just financial benefits. We note that the network provider will not be able to capture all of the benefits of next generation broadband, even when considering just private benefits along the whole value chain. We also note that an economist might view all economic and social costs and benefits as "economic". For example, as Frontier Economics commented in a study for DCMS:

> *"There appears to be a relatively artificial distinction between economic and social outcomes… While the literature is trying to measure social outcomes that are harder to place a value on, it is not clear that there is an obvious distinction between these and what are classified as economic benefits. Moreover, the framework identified (…) for measuring the benefits of cultural investment remains valid for identifying and measuring social benefits.*[20]

However, we have maintained a distinction between wider economic and wider social costs and benefits. Whilst there is potentially some overlap, double counting can be avoided provided care is taken when considering particular applications and impacts.

There are a number of pseudo costs and benefits that should not be counted because they are irrelevant or are counted elsewhere and therefore risk double counting. For these reasons asset price changes (if already captured under private cost-benefit), pseudo externalities, direct employment effects and competitiveness are not included in the overall cost-benefit analysis, however, for purposes of clarity they are described in more detail later in this chapter. We also note that benefits in terms of overall productivity and GDP are captured under economic benefits and do not need to be considered separately – they are not external to private benefits.

[20] Frontier Economics. 2007. "A framework for evaluating cultural policy investment." http://www.culture.gov.uk/Reference_library/rands/research/framework_ecpi.htm

Before considering each category in greater detail, it is important to be clear about wider or second round impacts. By second round effects we mean impacts throughout the economy beyond the immediate impacts. In relation to private benefits in undistorted markets, no account should be taken of second round effects.[21] This is consistent with UK Government Regulatory Impact Assessment (RIA) guidance which recognises the risk of double counting:

> *"In general, the analysis of costs and benefits will need to quantify only the **first–round** effects of proposed measures."*[22]

This conclusion reflects the fact that costs and benefits beyond immediate impacts represent a redistribution of primary costs and benefits rather than involving additional net impacts.

However, in considering wider economic and social costs and benefits second round effects may be important. For example, the indirect impacts of next generation broadband on greenhouse gas emissions (via increased demand for server capacity and behavioural changes) may dominate the impact of building and operating a next generation network. The reason for excluding second round effects in relation to private benefits yet considering them in relation to wider costs and benefits is that the former effects occur via the market whereas the latter may not.

Finally, we note that the benefits and costs of next generation broadband will turn out to differ in important ways from those anyone can anticipate, particularly in relation to new applications that do not currently exist. As Anderson and Stoneman (2007) put it:[23]

> *"...impacts may be 'bad' (internet steals social time) or 'good' (email generates new social connections) and much time and energy has been wasted debating whether bad predominates over good, whether utopia predominates over dystopia. All of this misses the point... technology does not and has never had a simple linear predictable impact on society."*

In conclusion, any *ex ante* assessment of a new technology will be incomplete and a degree of modesty is called for in undertaking an impact assessment. It also follows that excessive precision in relation to the things we can anticipate can mislead one into a false sense of confidence in the results. At this stage developing a clear framework and robust process for considering the value of next generation broadband is a necessary first step in identifying areas where further work might provide better estimates of value.

3.3 Framework Summary

Table 3-1 sets out comprehensive and non-overlapping categories of private and wider economic and social costs and benefits in the first three columns, and categories of cost and benefit that should not in general be considered (in magenta) in the fourth column. Below the table we provide a summary of what the horizontal categories represent. An explanation of the other categories is provided in the rest of this section.

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[21] Boardman, Greenberg, Vining and Weimer. 2006. "Cost-benefit analysis – concepts and practice." Third Edition. Pearson Prentice Hall.

[22] BERR. May 2008. "Impact assessment toolkit." Section on coverage of costs and benefits. http://www.berr.gov.uk/bre/policy/scrutinising-new-regulations/preparing-impact-assessments/toolkit/page44199.html

[23] Anderson and Stoneman. 2007. "Predicting the socio-technical future (and other myths)." Chimera Working Paper Number 2007-10. http://www.essex.ac.uk/chimera/content/pubs/wps/CWP-2007-10-predicting-socio-tech.pdf

Table 3-1: Overview of framework for considering costs and benefits

Private	Wider economic	Wider social	Pseudo – not counted
Private costs are the resource costs of next generation broadband valued in the market Private benefits include: (i) Saving time doing what one would do anyway (ii) Doing more of existing things (iii) New things and transformations	Non-appropriable private Externality Piracy Network effects Spill-over and virtual agglomeration Competition in telecoms sector and wider economy Resilience, adaptability and policy options Excess burden of taxation	Educated citizens Informed democracy and freedom of expression Cultural understanding Belonging to a community and inclusion Privacy Social capital, resilience and trust	Pseudo externalities Asset price changes (if already captured under private cost-benefit) Employment effects "Competitiveness"

Private costs and benefits are valued by individuals and the market, and can be expressed in money terms. We include services purchased by the government within this category.

- Private costs of building a next generation broadband network (net of any operating cost savings).
- Saving time refers to doing what one does now online but more efficiently and productively.
- Doing more refers to doing more of things one can do online now, but which may be constrained by bandwidth.
- Doing new things refers to new applications enabled by next generation broadband such as HD 2-way video.

Wider economic costs and benefits involve a divergence between private and economic value to society.

- Non-appropriable private refers to circumstances where potential private resource value cannot be captured by investors i.e. some radio spectrum and land and buildings.
- Piracy refers to illegal copying and distribution of content.
- Network effects refer to the benefits arising from others using an application (Metcalfe's law).
- Spill-over and virtual agglomeration refers to the positive impact of agglomerations on productivity achieved without agglomeration.
- Resilience, adaptability and policy options refer to improved supply chain management, resilience to shocks and enhanced flexibility in terms of policy options.
- Excess burden of taxation refers to the economic costs of raising public finance.

Wider social costs and benefits refer to social impacts. These categories are reasonably self explanatory and involve wider citizen costs and benefits not captured under the categories private and wider economic.

Pseudo costs and benefits includes considerations that should not typically be counted as costs or benefit since they are either irrelevant or should have been counted elsewhere.

- Pseudo externalities that involve second round impacts mediated within markets that should not be counted.
- Asset price changes that typically reflect flows of costs and benefits that should not be double counted.
- Employment effects generally involve a reallocation of jobs with no net impact.
- "Competitiveness" overlaps with productivity, which is reflected in private and wider economic benefits.

3.4 Private costs and benefits

3.4.1 Private costs

Private costs include the capital and operating costs of next generation broadband, and potential operating cost savings that may result from the deployment of next generation broadband access. These costs can be valued at market prices.

Private costs will also include the costs for consumers, service providers and network operators of upgrading end user equipment, wireless routers, household wiring, elements of the core network and servers to support services over next generation broadband. Unless these constraints are addressed, either pro-actively or via the progressive substitution of new for old equipment, over time they would limit the potential benefits of next generation broadband.

3.4.2 Private benefits

There are three categories of private benefit – within which we include government services[24] – which would be associated with the attributes of next generation broadband:

1. Doing what people do now, but in less time – thereby enabling higher productivity and/or more time for alternative activities (these benefits should be realisable in the short-term).
2. Doing more of existing things where next generation broadband improves the experience most – particularly rich content sharing, viewing and forms of collaboration. Overall, a change in the balance of activities online could be expected. (These benefits should be realisable in the short to medium-term).
3. Doing new things involving transformations of the way we live, work, and create and distribute content and data (these benefits should be realisable in the medium to long-term).

The above categories range from static to dynamic in terms of the amount of change involved and therefore the likely timeframe over which benefits might occur. The first category of benefits should accrue quickly once next generation broadband is available, while the second category will tend to emerge in the short to medium term. There is likely to be a more significant time lag before the transformational benefits are realised, and it is likely that these would build up over a decade or so.

[24] Purchasing agencies such as the NHS and DFES are best placed to trade-off inputs in producing desired outputs, and are able to express their willingness to pay in the market. Treating next generation broadband as an input to production of government services like any other input is also likely to promote efficiency compared to an approach where next generation broadband is viewed as an input that should be subsidised to support the production of public goods. Diamond and Mirrlees (1971) found that in setting policy to maximise welfare in a second-best situation it is not desirable to tax (or subsidise) the use of particular inputs to the production process. "Optimal taxation and public production 1: Production efficiency and 2: tax rules". *American Economic Review*, Volume 61. For an applied discussion of these principles in relation to spectrum pricing and broadcasting see: October 2005. "Study into the potential application of Administered Incentive Pricing to spectrum used for Terrestrial TV and Radio Broadcasting." http://www.ofcom.org.uk/consult/condocs/futurepricing/aipstudy.pdf

3.4.2.1 Constraints on the ability of investors to realise private value

Willingness to pay for next generation broadband can be expected to reflect private incremental benefits. However, there will be underlying constraints on the ability of investors to realise the full private benefits of next generation broadband.

- To the extent that next generation broadband is an experience good (consumers have to try it to appreciate it) users may not appreciate the benefits and be willing to pay a significant premium for it until they have experienced it and adapted their behaviour and/or the technology and services offered, as proved the case with broadband.[25] This adjustment in consumer understanding of the benefits would take time.
- There will be additional constraints where the creation of new value chains – and potentially the destruction of old ones – is required. Potentially disruptive transformations involve high levels of uncertainty over what model will work best and who will capture the benefits. Further, getting the strategy right is likely to involve a set of complementary changes that are unlikely to be discovered incrementally.[26] A lack of competition in new markets could also weaken incentives due to the absence of market-based comparisons against which to benchmark performance.[27] Such constraints are an underlying reality in markets, and there may be no feasible intervention that would lessen their impact. The fact that some internet applications may be non-monetisable in themselves does not imply that they do not add realisable value in relation to next generation broadband (since they may shift out the demand curve for next generation broadband).
- Information constraints in terms of knowing who would pay how much will limit the ability of investors to capture consumer willingness to pay in relation to next generation broadband. A single tariff yields, at most, the revenue represented by the square P* x Q* in **Figure 3-1** below, which is less than the investment cost shown by the larger square. In other words, tiered pricing will be important for enabling operators to capture more of the value that consumers will be willing to pay (see **Figure 3-2**). Inefficient regulation could compound this problem if it limited price flexibility and the ability to experiment with different price and service plans (other regulatory constraints could also drive a wedge between private value and investor value).

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[25] See OECD for a range of examples. December 2007. “Broadband and ICT access and use by households and individuals.” http://www.oecd.org/dataoecd/44/11/39869349.pdf

[26] John Roberts. 2004. “The modern firm”. Oxford University Press. Where complementarities exist between a set of factors, in the sense that an increase in one variable (say new video distribution models) raises the incremental return to an increase in other factors (NGA), incremental profit maximising behaviour will not necessarily lead to the best possible outcome and a strategic move is required.

[27] Farrell, Joseph. February 1983. “Monopoly Slack and Competitive Rigor: A Simple Model”. MIT mimeo. In Rasmusen (Ed). 2001. “Readings in Games and Information.” Pages 169-172. Blackwell Publishers.

Figure 3-1

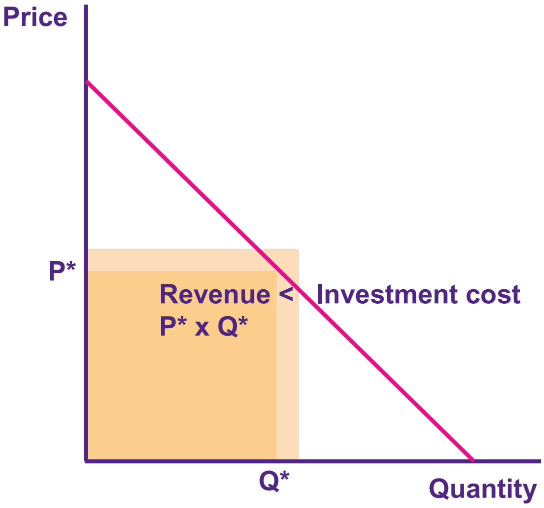
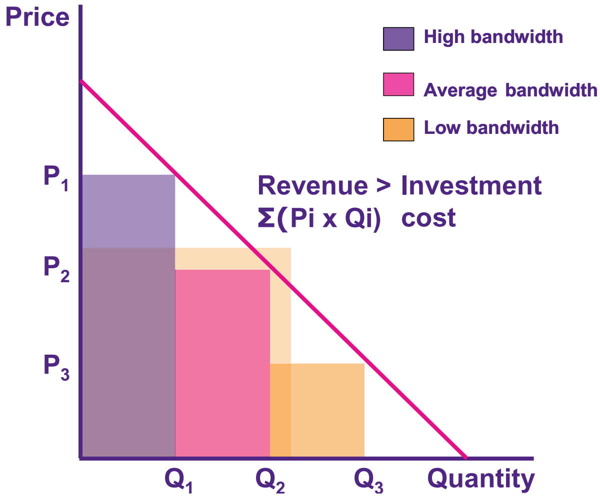


Figure 3-2



In conclusion, some constraints may be unavoidable and limit the potential to realise value, or slow transformation down as new opportunities are explored and new relationships in the value chain are negotiated. Others could be eliminated or minimised via the development of appropriate policy and regulatory frameworks in relation to next generation broadband investment and related elements of the value chain.

3.4.2.2 Government services and private value

In some discussions government services and wider social value are treated synonymously (many past reports on the value of broadband argue that significant efficiency gains might be made in regard to public services and in particular, health and education). However, in many cases efficiency gains in relation to public services will be internalised either by the citizen using the service or by the agencies delivering them and passed on to users in improved services or reduced taxes. We therefore account for public services purchased by a central agency under private value, and consider other categories of wider social value related to government objectives under wider social value.

We also note that there are constraints which apply to the realisation of potential value in relation to government services and which differ from those applying in the private sector. These are set out below in Box 3-1.

Box 3-1: Constraints on achieving benefits in relation to government services

Government may find it particularly difficult to realise the potential of next generation broadband in public service delivery due to a desire to provide services universally which limits scope to phase out legacy approaches; and due to "agency problems" – problems of aligning behaviour when information is imperfect and asymmetrically distributed – in terms of incentives to take appropriate risk, to close down failing initiatives in a timely manner and to take account of citizens' preferences in terms of service quality including convenience and the value of their time. In the absence of market pressure to reflect user preferences and costs in service provision, the focus tends to be on centrally determined objectives and financial cost minimisation (which should at least reflect the value within government of time savings, doing more and doing new things). We note that these constraints may be smaller where there is relatively more decentralisation, for example, in local rather than national government or in relation to education versus health.

A partial remedy to these constraints would be to explicitly value user/citizen costs – including the value of their time (as is currently the case in relation to transport projects) – in the appraisal of government services provision. We note that many of the policy priorities related to health services for example, such as reducing waiting lists, reducing waiting time in A&E, extending GP opening hours and online booking services all fundamentally seek to save time and increase convenience for citizens.

In some cases, in order to move to more efficient forms of delivery it may be appropriate for a public sector agency to subsidise an individual's broadband connection, where this individual could be a government employee delivering a service (e.g. a health care professional) or a user consuming it (e.g. a patient). An example of this is the Department for Children, Schools and Family home access to technology proposals, which proposes to subsidise IT and broadband connections for school children who would not otherwise have broadband access at home.[28]

3.4.3 Saving time

This benefit would be the most straightforward to value, if we knew what people did online. We have estimates of the value of people's time from research on the value of travel and other time-savings (time savings are a key consideration in transport cost benefit studies[29]). Based on the value of time used in transport and other evaluations, and the amount of time people spend online, even modest savings in time could be very valuable in aggregate.

3.4.4 Doing more

A reduction in the time required to upload and download data would change behaviour since the relative user "cost" of online activities such as content rich collaboration (including video calls), uploading and sharing content (particularly photos and video) and downloading of music and particularly HD video would all fall.

Whilst some users currently do things that would work more effectively over higher speed connections, they would no doubt do more and others would join them if less waiting was involved and the quality of the experience was better.

3.4.5 Doing new things

Almost by definition, this is the hardest category of change to anticipate. Users may not anticipate how next generation broadband would change their behaviour, particularly given that the services and business processes that might be common place with next generation broadband may not yet exist or only exist at the fringe today.

However, some emerging changes may become widespread, particularly those related to online distribution of video content, richer real-time collaboration, two-way video communication including

[28] DFES. January 2008. "Home access to technology." http://www.dfes.gov.uk/consultations/downloadableDocs/Home%20Access%20Consultation%20Document%20revised.pdf

[29] Department for Transport. 2003. "Value of travel time savings in the UK: summary report." http://www.dft.gov.uk/pdf/pgr/economics/rdg/valueoftraveltimesavingsinth3130

'telepresense' and monitoring and new IT service models where networked storage, collaboration and software increasingly replace their local equivalents.[30]

Such applications could, in time, have significant material impacts in terms of private benefits. Developments of currently unknown services and applications may well have transformational impacts on consumers and businesses. They could also be used to transform the way in which citizens access and interact with public services such as health and education and, for example, be used to improve social inclusion for groups such as those with limited mobility or other forms of disability.

3.5 Wider economic costs and benefits

Beyond private costs and benefits there may be wider economic costs and benefits that are not reflected in the costs faced by investors or in individual's private willingness to pay for next generation broadband.

In relation to next generation broadband, we consider the following categories of wider social costs and benefits: non-appropriable private value; externality; piracy; network effects; spill-over and virtual agglomeration effects; competition in the economy; resilience, adaptability and policy options; and potential excess burden of taxation.

The list is not necessarily exhaustive, however we consider that most wider economic costs and benefits should be captured by these categories.

3.5.1 Non-appropriable private value

We refer to circumstances where potential private resource value associated with next generation broadband cannot be captured by potential investors as non-appropriable private value. The focus is narrower than value that may be hard to capture by investors in relation to the extended value chain enabled by next generation broadband. We are interested within this category in existing policy and contractual constraints on the realisation of value by investors from "property", including land and buildings and UHF radio spectrum which could be released in the longer term as a result of next generation broadband deployment.

3.5.2 Externality

Externalities arise when economic activity generates costs or benefits for third parties that are not mediated by the market, for example, the impact of greenhouse gas emissions from power generation on global climate and therefore on the wellbeing of others. Externalities that might be identified in relation to next generation broadband include:

- Costs in terms of road traffic congestion/disruption during the laying of buried fibre.

[30] Analogous to the transformation of electricity production and use that began roughly a century ago. Jovanovic and Rousseau. January 2003. "General purpose technologies." http://www.econ.nyu.edu/user/jovanovi/GPT.pdf

- Any reduction in traffic congestion from the increased scope to substitute working at home and telepresence for travel.
- The impact of laying and operating fibre, and the direct and indirect impact of services provided over next generation broadband, on greenhouse gas emissions.

3.5.3 Piracy

Piracy may involve economic costs in terms of the transaction costs of efforts to limit piracy (both for consumers and producers) and the chilling effect it may have on production and effective distribution of new content.

3.5.4 Network effects

Network effects arise when the value to each user of a network depends on the number of other users on the network. The value of one new user joining the network will then be greater than the value to that user, since all other users are better off as they now have the opportunity to communicate with the new user (the opposite happens with traffic congestion where each additional user imposes a cost on others). This additional benefit of each user joining the network is known as a network externality. One formulation of network effects is known as Metcalfe's Law which states that the value of a network grows as the square of the number of users.

Fixed and mobile telephony networks are good examples of networks where a network externality applies, at least at the time when penetration is well below 100 per cent. In order to capture network effects investors might offer cross subsidies to promote rapid take-up, and regulators/governments might allow regulated prices that differ from costs (e.g. in regulated mobile termination rates) or provide funding.

3.5.5 Spill-over and virtual agglomeration benefits

ICT and broadband improve information flows and open up new ways of organising economic activity and of collaborating – they might therefore be expected to enhance knowledge spill-overs (which may be non-local).

There is also evidence of positive externalities in terms of productivity from agglomeration i.e. spatially concentrated economic activity, particularly in cities.[31] This has become a focus of attention in relation to transport infrastructure and transport project appraisal (including London Crossrail) with the benefits of agglomeration identified by the 2006 Eddington Transport Study:[32]

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[31] Venables. 2004. "Evaluating urban transport improvements: cost-benefit analysis in the presence of agglomeration and income taxation." http://www.econ.ox.ac.uk/members/tony.venables/Xrail7.pdf

[32] The Eddington Transport Study. December 2006. The case for action: Sir Rod Eddington's advice to Government." Figure 2. http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/

See also Eddington and Department for Transport. December 2006. "Agglomeration in the UK and role of transport policy." Research Annexes: Volume 1. Paragraphs 14 and 15. http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/researchannexes/researchannexesvolume1/

> *"Transport improvements can expand labour market catchments, improving job matching, and facilitate business to business interactions. Transport's contribution to such effects is most significant within large, high-productivity urban areas of the UK. London is the most significant example, adding 30 per cent to the time saving benefits of some transport schemes."*

A subsequent review of transport appraisal notes that:[33]

> *"…reducing transport costs can bring firms and workers closer together, generating benefits from better functioning markets. Empirical evidence has shown that in an area with a mass of firms and workers, i.e. an agglomeration, there is often a productivity premium. This premium may result from increased access to product and input markets and the sharing of knowledge and expertise."*

In conclusion, spill-over and agglomeration benefits refer to the economic benefits of improved networks and interaction that are external to individuals. Next generation broadband may enable virtual agglomeration benefits to be captured without proximity, and over a wider area.

3.5.6 Competition in the economy

Competition within the economy is a driver of innovation and efficient investment. Next generation broadband would impact on the nature of competition within the telecommunications market, and could alter competition in the rest of the economy by increasing the potential for trade in services and the efficiency of labour markets.

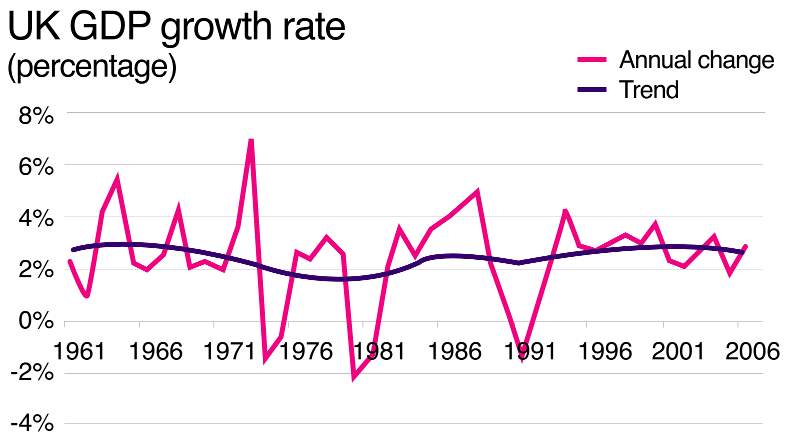
3.5.7 Resilience, adaptability and policy options

Over time economic output and incomes have grown, but they are subject to fluctuations induced by shocks to the economy that are costly to individuals and businesses who must manage changes in their circumstances, including dislocation of their employment and periods of unemployment for some during economic downturns. **Figure 3-3** shows trend GDP growth and fluctuations since 1960.

The economy has been more stable over the past two decades or so, and this phenomenon has been observed across the G7 economies and is referred to in the US as the "great moderation" (capital market developments during 2007/08 may test this stability in the short term). The "great moderation" has contributed to substantial economic and social gains via the avoidance of periodic dislocation in society.

[33] Department for Transport. October 2007. The NATA refresh. http://www.dft.gov.uk/consultations/closed/consulnatarefresh/pdfnatarefresh.pdf

Figure 3-4: GDP growth and fluctuations



Source: ONS, Trend growth calculated using Hodrick-Prescott filter

Fluctuations in output are driven by demand side shocks (e.g. consumer confidence) and supply side shocks (e.g. oil price shocks). The extent of ICT use and network connectivity in particular, are thought to have reduced volatility to demand side shocks by improving supply chain management and lowering inventories that amplify demand side fluctuations, and may also increase resilience to supply side shocks by offering substitution possibilities.[34]

Commenting on the contribution of ICT and connectivity, Summers (2005) notes:[35]

> "the volatility of durable goods sales has remained essentially constant, while the volatility of production has declined by an amount similar to that of GDP.... Such changes might have *occurred in at least two ways. First, by making production or sales less sensitive to inventories, improved sales forecasting or inventory management could have reduced the volatility of inventory investment within a particular industry. Second, similar improvements in supply, distribution, and transportation networks might have helped streamline connections among* industries (such as auto manufacturing and retailing)."

3.5.8 Excess burden of taxation

Considerations about the potential excess burden of taxation (deadweight loss) would only be relevant if the government contributes resources towards next generation broadband investment. If public funds rather than voluntary user payments are used to fund next generation broadband, then an additional cost is incurred in terms of the economic cost of raising taxes. This is the so called deadweight loss or excess burden which refers to the economic welfare cost due to reduced incentives to participate in the labour force and to save and invest arising from taxation.

[34] For a discussion of resilience see HM-Treasury. March 2008. "Resilience in the UK and other OECD economies: Treasury Economic Working Paper No.2." http://www.hm-treasury.gov.uk/budget/budget_08/documents/bud_bud08_resilience.cfm

[35] Summers. 2005. "What caused the great moderation? – Some cross-country evidence." Federal Reserve Bank of Kansas City: Economic Review, Third Quarter. http://www.kansascityfed.org/Publicat/econrev/PDF/3q05summ.pdf

3.6 Wider social costs and benefits

There is a range of other costs and benefits beyond private and wider economic costs and benefits. In deciding on a set of categories we considered Ofcom's work in relation to the Digital Dividend Review,[36] literature on technology assessment, the European i2010 initiative,[37] and the Ofcom consultation on next generation access.[38]

New technologies can be used for pro-social outcomes or for anti-social outcomes. Broadband can be used to vote, campaign, participate and educate, but it can also be used to consume anti social content in ways likely to entail negative externalities for society as a whole. Next generation broadband, like other communications technologies can enhance cultural exchange and understanding between groups, but it could also enable intensification of what Cas R. Sunstein called the 'Daily Me' effect, whereby users are more exposed to views more like their own due to the fragmentation of communication space. However, we note that any new technology is likely to have beneficial and harmful impacts, and that individuals, policy and regulation can be expected to adapt to mitigate any harmful impacts.

Clearly we are dealing with highly complex and indeterminate effects. This does not mean that it is impossible to comment on potential wider social costs and benefits associated with next generation broadband.

Further, whether it is claimed that there is a net social value benefit associated with a given technology very often depends on a simple problem of definition: some analysts see 'virtual participation' as positive and genuine engagement with democratic and social benefits, and others see it as by definition anti-social in that it takes time away from face to face interaction and engagement.[39]

We acknowledge that making definitive statements about the wider social costs and benefits of future technologies is particularly difficult in the light of uncertainties about impacts. What we hope is that a more qualitative discussion can help inform future choices.

We have identified the following list of categories where we believe that there may be potential wider social impacts that should be considered. They include: educated citizens; informed democracy, cultural understanding and social inclusion; home working and its impact on community and education; inclusion and disability; and social capital, resilience and trust.

[36] Ofcom. December 2007. "Digital dividend review: a statement on our approach to awarding the digital dividend." Page 28. http://www.ofcom.org.uk/consult/condocs/ddr/statement/statement.pdf

[37] European Commission. 2005. "i2010 – A European Information Society for growth and employment." http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0229:FIN:EN:PDF

[38] Ofcom. September 2007. "Future broadband – policy approach to next generation access." Paragraph 7.7. Ofcom concluded that there was limited evidence of incremental social value from next generation broadband, but noted that in advance of deployment we need to consider how the applications and services that next generation networks would deliver may contribute to social value.

[39] Robert Puttnam, for example argues that television use negatively impacts on participation and social capital in his book 'Bowling Alone', whereas Martin Brookes' research for the BBC 'Watching Alone' stresses the fact that television itself can generate shared experience and social capital: it can constitute participation in society. Robert Puttnam. 2000. "Bowling Alone". New York Simon and Shuster; Martin Brookes. 2004. "Watching Alone: Social Capital and Public Service Broadcasting". London, BBC/The Work Foundation.

3.7 Distributional impacts

The HM-Treasury Green book defines distributional impacts in terms of the impact of costs and benefits across different groups that should be considered in policy appraisal.[40] All of the costs and benefits mentioned in this section could be appraised in terms of the nation as a whole and the distribution across different groups. In particular, HM-Treasury identifies income, gender, ethnic group, age, geographical location and disability as categories to consider. A number of these categories reflect non-discrimination principles enshrined in law. Distributional impacts in relation to next generation broadband may be related to its availability and use by different groups or regions in particular.

3.7.1 Availability of next generation broadband

Since next generation broadband requires substantial investment it will only become available progressively, and commercial rollout is likely to stop well short of 100 per cent coverage. A transition period in which next generation broadband is only available to some is therefore inevitable.

In these respects next generation broadband differs from existing broadband, which, although it got off to a slow start, was made available to a large proportion of households in the UK relatively quickly. Next generation broadband also differs from existing broadband in that once it is available, performance would be much more uniform (although the extent of that uniformity may depend upon the technology used).

The commercial rollout of next generation broadband would be likely to focus primarily on towns and cities. This will mean that regional disparities of next generation broadband provision are likely to be more pronounced and prolonged than they were for first generation broadband. Next generation broadband may also have indirect spatial impacts via its impact on economic activity.

3.7.2 Take-up of next generation broadband

Whilst widespread availability of next generation broadband would take some time to occur, take-up will follow a diffusion curve with different groups opting for the technology at different times. The diffusion of broadband provides one basis on which to judge how take-up might vary across groups in relation to next generation broadband. We note that the diffusion of broadband has been very rapid in comparison with most other technologies, and in common with many other technologies initial diffusion tends to be focused on younger, more highly educated richer households – with diffusion spreading to other groups over time. Any new technology will initially involve a "divide", which will tend to close as penetration rises.

With next generation broadband the pattern of diffusion will in all likelihood be very different. First, as discussed earlier availability will be more uneven for longer given the investment and time required to rollout next generation broadband. Second, new build sites will be the first to get next generation broadband and these sites may cover a wider cross section of people than typical early adopters. Third, if price differentials between existing and next generation services persist the market may remain segmented, with some preferring a cheaper lower quality service.

[40] http://greenbook.treasury.gov.uk/

3.8 Pseudo costs and benefits that should be excluded

It is important to clarify categories of costs and benefits that are often mentioned in relation to costs and benefits generally and that should not be included in the framework because they are not relevant or because they are already accounted for elsewhere.

3.8.1 Pseudo externalities

There are a number of categories of costs and benefits that do not impact an overall assessment of net national benefit, but instead involve a redistribution of gains and losses throughout the economy. Including these in an overall assessment of costs and benefits would result in double counting (distributional impacts are of course of interest in their own right – but this should be considered separately). A text on cost benefit analysis sets out the issue in terms of primary and secondary market impacts as follows:[41]

> *"We can, indeed should ignore impacts in undistorted secondary markets as long as changes in social surplus in the primary market resulting from a government project are measured and prices in the secondary market do not change." Page 113; and*
>
> *"We should ignore effects in undistorted secondary markets, regardless of whether there are price changes, if we are measuring benefits in the primary market using empirically measured demand schedules that do not hold prices in secondary markets constant." Page 118*

The environmental economics literature also points to the risk of counting so called pseudo externalities:[42]

> *"There is a category of pseudo-externalities, the pecuniary externalities, in which one individual's activity level affects the financial circumstances of another, but which need not produce a misallocation of resources in a world of pure competition…Pecuniary externalities result from a change in the prices of some inputs or outputs in the economy. An increase in the number of shoes demanded raises the price of leather and hence affects the welfare of the purchases of handbags. But unlike a true externality… it does not generate a shift in the handbag production function."*

By second round effects we mean impacts throughout the economy beyond the immediate impacts. In relation to private benefits in undistorted markets, no account should be taken of second round effects. This conclusion reflects the fact that costs and benefits beyond immediate impacts represent a redistribution of primary costs and benefits rather than involving additional net impacts.

However, in considering wider economic and social costs and benefits second round effects may be important. Noise, smoke and greenhouse gas emissions are legitimate externalities; the impact of next generation broadband investment on labour demand and other investors' costs is not. Legitimate externalities should also only be counted once if they are already internalised in market prices via policy interventions such as taxes and tradable permits.

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[41] Boardman, Greenberg, Vining and Weimer. 2006. "Cost-benefit analysis – concepts and practice." Third Edition. Pearson Prentice Hall.

[42] Baumol and Oates. 1988. "The theory of environmental policy." Second edition. Cambridge.

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Some studies suggest that productivity and GDP impacts *per se* are externalities. In general they are not. Productivity gains result in higher real earnings and/or profits; whilst GDP is simply productivity per hour worked times hours worked i.e. these macroeconomic measures represent the sum of private behaviour where rewards are to a significant extent internal to individuals.

Our approach to the assessment of costs and benefits is to consider specific applications and categories of costs and benefits – rather than adopting a "top down" approach to estimating the impact on productivity and GDP – on the grounds that this approach is likely to be more informative and captures a wider range of costs and benefits not necessarily reflected in productivity and GDP.

3.8.2 Changes in asset values

Impacts on the value of existing assets should not be counted in addition to direct costs and benefits to producers and users. For example, if the value of next generation broadband drove up house prices where it was available (indeed there is evidence that broadband drove up house rental prices in the US),[43] this is an alternative means of valuing consumer surplus (private willingness to pay less cost), rather than an additional value that should be counted.

Another example is the fact that new technology often drives down or destroys the value of existing assets, for example, electricity progressively destroyed the value of local steam power plants early in the 20th Century. To the extent that technological progress is anticipated firms raise their prices to compensate for the anticipated loss of value as better technology is introduced over time (this effect will occur in competitive markets). To the extent that technological change is not anticipated firms make windfall gains and losses.

Were next generation broadband investment to occur, strictly speaking the economic life of some legacy assets would fall to zero i.e. there would be no further life to consider. An important qualification here is that asset values may legitimately be included where the related costs and benefits are not counted elsewhere, for example, potentially non-appropriable value from the release of land and buildings and radio spectrum.

3.8.3 Employment effects

Investment in next generation broadband would create demand for specific work during the build phase, and could result in a substantial reallocation of jobs out of the sector once the network is built (a key benefit of investment in telecommunications over the past few decades has been the destruction of jobs in the sector i.e. productivity gains).

Whilst jobs would be created and destroyed throughout the economy due to next generation broadband (just as broadband has created and destroyed specific jobs), there are no grounds for presuming that there would be a net direct impact on employment in the economy overall. Further, worthwhile investments, namely those with social returns exceeding their costs, do result in improved outcomes in terms of productivity and therefore real incomes and/or leisure (the quality of jobs).

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[43] Lehr, Osorio, Gillet and Sirbu. January 2006. "Measuring broadband's economic impact." http://cfp.mit.edu/groups/broadband/docs/2005/MeasuringBB_EconImpact.pdf

There may also be an indirect impact if next generation broadband impacts on the efficiency of the labour market by improving labour market search and matching via two way video in particular – an impact we consider under competition in the economy. Further, to the extent that improved connectivity improves economic stability it may lower equilibrium unemployment.

The key point is that one should not count additional labour requirements within the telecommunications or contracting sectors during the build of next generation broadband, or possible reductions in labour requirements within the sector following completion of a next generation broadband network, as implying net impacts on aggregate employment.

3.8.4 "Competitiveness"

Competitiveness, particularly national competitiveness is sometimes referred to in a way that suggests it is somehow additional to efficient and timely investment or productivity growth. However, only investment that is efficient and timely – or alternatively has a positive value – will lead to growth in national income. As economist Paul Krugman put it:

> "*it is simply not the case that the world's leading nations are to any important degree in economic competition with each other*."[44]

Productivity growth is the source of real income growth in the long run, and we are interested in the impact of next generation broadband on productivity and productivity growth (captured under our measures of private and wider economic benefits). However, productivity gains result in wage and exchange rate movements that offset apparent gains in competitiveness at the national level.

What happens over time is that a country's comparative advantage shifts and resources are reallocated to their most productive use, creating new activities and destroying others. We aim to capture such benefits directly rather than under the category "competitiveness".

Investing in something simply because others have does not make economic sense. The case for investment should rest on the resource cost and expected returns within the UK. If others invest in next generation broadband the UK is not necessarily getting left behind in terms of economic and social progress, because others may be investing prematurely or for reasons that make sense locally. If others invest and the UK does not, then there would be implications for the mix of activity in the economy.

For example, some services including those in the creative economy would benefit from the availability of next generation broadband and ultimately be disadvantaged by its absence (though where the economic payoff is very large investment in point to point fibre can be expected in the absence of wide area next generation broadband). However, this is an issue of sectoral mix in the economy, and next generation broadband should still past the test of net investment benefit if it is of value to the economy overall.

The fact that others are investing may change the best estimate of costs and benefits for investment in the UK for a number of sound reasons:

- Market outcomes where others have invested provide new information about costs, demand and willingness to pay.

[44] Krugman. March/April 1994. "Competitiveness: a dangerous obsession." *Foreign Affairs*. http://www.pkarchive.org/global/pop.html

- Global orders for equipment will establish standards and contribute to global scale in manufacturing, thereby lowering costs (though some costs could rise in the short run, for example, in relation to particular skills where labour is free to move).
- Investment in next generation broadband by others contributes to global network effects, for example, perhaps establishing video collaboration as a standard tool in global supply chains.
- The development of applications and services around next generation broadband will enlarge the market that can be tapped quickly in relation to any local investment.

The key point is that whilst what others do may change the expected costs and benefits of investment in next generation broadband in the UK, it is not the fact that others are investing *per se* that should motivate investment. Investment should be judged on its merits in terms of productivity, consumer welfare and wider gains.

4 Alternative broadband scenarios

'The services are not yet defined, the technology is not yet stable... ' Ofcom chairman Lord Currie, speaking to the Communications Management Association Conference, 2007

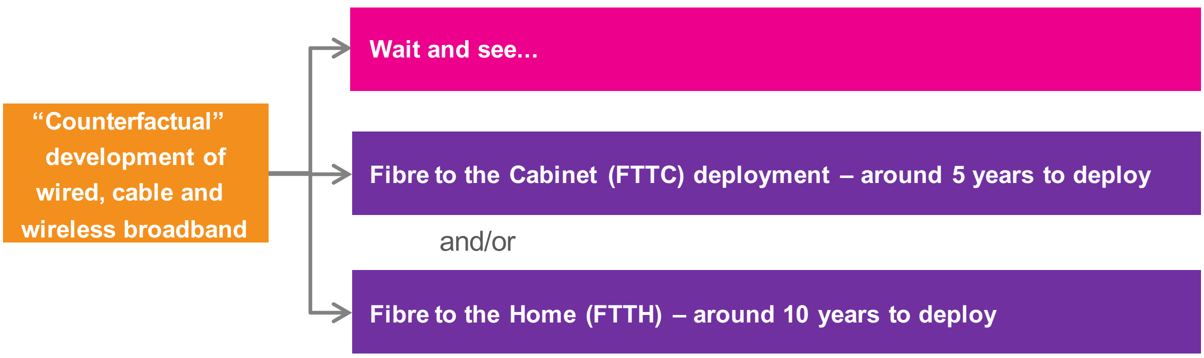
4.1 Introduction

In this section we set out the four scenarios. Firstly we set out the counterfactual, which describes what we know about future developments. Secondly we describe the option to wait and see and deploy later rather than earlier. We then describe deployment scenarios for fibre to the cabinet and fibre to the home.

In considering the value of next generation broadband we consider the incremental value of wide spread availability and take-up of next generation broadband against a counterfactual that includes the evolution of existing platforms with upgrades to existing copper, cable (with DOCSIS 3.0) and wireless networks; and no wide area fibre beyond new build (beginning with the Ebbsfleet development in Kent in Autumn 2008).[45]

Timing is explicitly considered since the option to invest in next generation broadband now or in the future exists. In terms of next generation broadband scenarios, we consider the option to wait and see (and potentially invest at some point in future), and the option to invest in the extension of fibre optics closer to, or all the way to the customer premise in the near term. We consider Fibre to the Cabinet (FTTC) where fibre is taken to a street cabinet and existing copper used for the final connection to premises, and Fibre to the Home (FTTH) where fibre is taken all the way to the premise where optical signals are converted to electrical ones. These options are not necessarily mutually exclusive, and are included to give a feel for the range of potential performance and cost involved. Figure 4-1 illustrates the scenarios.

Figure 4-1: Scenarios



We assume availability to 80 per cent of the population of the UK, corresponding to towns and cities, in our fibre scenarios. Beyond this level of coverage costs are likely to rise significantly and commercial rollout is less likely to be feasible in the foreseeable future. We discuss the question of whether further rollout would bring additional benefits following our assessment of costs and benefits

[45] A number of other studies have considered the value of broadband or the total value of next generation broadband, broadband and development of core networks. This study is more narrowly focussed on the incremental benefits of next generation broadband.

for the 80 per cent availability scenario. We also assume rollout of FTTC over 5 years and FTTH over 10 years or more.

4.2 The counterfactual

The possibility of investing in next generation broadband and the benefits that would flow from doing so do not exist in a vacuum. The counterfactual includes the evolution of existing platforms, and no wide area fibre beyond new build. In particular the counterfactual includes (or soon will):

- Broadband penetration in the UK exceeds 57 per cent of households and continues to grow.[46]
- DSL over telephone lines accounts for around 78 per cent of overall broadband take-up, and provides national coverage of around 99 per cent.[47]
- DSL is moving to faster ADSL2+ technology with some unbundled local loops already utilising ADSL2+, and BT rolling out an upgrade to ADSL2+ technology ("Wholesale Broadband Connect") during 2008-2010. Appendix A provides details of the performance of copper based DSL.[48]
- Virgin Media are piloting a 50Mbps cable broadband service utilising DOCSIS3.0 technology in Kent, and plan to rollout the service during 2008 to more than 70 per cent of the 12.5 million homes covered by the cable network.[49]
- The first fibre to the premises service is expected to go live at Ebbsfleet this Autumn.[50] New site deployment beyond Ebbsfleet is subject to regulatory and industry agreements. However, proposed prices at Ebbsfleet are based on a rollout scenario of around 200,000 houses per annum out of a new build market of around 250,000 houses per annum.[51]
- H2O Networks Ltd announced plans in May 2008 to provide fibre connectivity to businesses and more than 88,000 homes in Bournemouth by laying fibre in the sewer network.[52]
- The public sector led Digital Region project has plans to provide FTTC in South Yorkshire covering 546,000 homes and 40,000 business.[53]
- More than 120,000 UK businesses are already connected to point-to-point fibre access.
- Terrestrial wireless data services over 3G and WiFi are moving to new standards that allow faster performance in both directions (3.5G including HSDPA and HSPA, and WiFi 802.11a, g and n). Appendix B provides details of the performance of wireless.

[46] ONS. August 2007. "Internet access 2007". http://www.statistics.gov.uk/pdfdir/inta0807.pdf

[47] Ofcom. 2007. Communications Market Report. Page 289.

[48] Higher speed services are also offered in the business market utilising multiple copper pairs (copper bonding). Our analysis focuses on mass market single line based DSL services.

[49] Virgin Media. 28 January 2008. "Virgin Media Boosts Britain's Broadband Speeds." http://pressoffice.virginmedia.com/phoenix.zhtml?c=205406&p=irol-newsArticle&ID=1100403&highlight=

[50] Openreach. 15 January 2008. "Openreach future access forum." http://www.openreach.co.uk/orpg/products/nga/downloads/Openreach%20Future%20Access%20Forum_15th_Jan_2008.pdf

[51] Openreach. 15 January 2008. "Openreach Future Access Forum. Record of the Event with Q&A." http://www.openreach.co.uk/orpg/products/nga/downloads/OFAF%20mtg%20mins%202008-01-15%20finalv2.pdf

[52] 7 May 2008. "Bournemouth becomes UK's first fibre city." http://www.fibrecity.eu/latest-news.htm

[53] http://www.digitalregion.co.uk/nextgen.html

- Satellite broadband services with data rates of up to 1.5 Mbps download and 512 kbps upload are offered across the UK, although penetration is currently very low at less than 0.1 per cent of the total broadband market.[54] Data rates are expected to improve in future, though satellite does not offer the same quality of service as copper or terrestrial wireless due to the signal delay associated with geostationary satellite systems. Appendix B provides details of the performance of wireless including satellite services.

In addition, satellite and terrestrial broadcast platforms will offer increased one-way capacity for HDTV with the recent launch of Freesat[55] and use of improved compression (MPEG4) and transmission (DVBT-2) expected to allow the launch of three terrestrial broadcast HDTV channels in 2009 and a fourth from 2012.[56] Additional broadcast HDTV could require utilisation of spectrum released at digital switchover in 2012 if existing SD channels are not shut down.

Computing power and software (which allow compression), memory and bandwidth are to some extent substitutes. Advances in memory and compression could reduce the bandwidth required to support a given service. Recent advances in storage and compression that have enabled new markets to develop include:

- MPEG2, which made DVDs feasible and is used for digital terrestrial TV broadcasting.
- MP3, which made online music distribution and file sharing feasible, and which, along with advances in hard drives and memory chips, led to the creation of the iPod.
- JPEG, a compressed format for photos, which has facilitated photo sharing online.
- MPEG4 (H.264/AVC), which reduces the size of video files compared to MPEG2 by half or more, was finalised in 2003. It is used by YouTube, for terrestrial TV in other countries, for HDTV including Sky HD, potentially future DTT broadcasting in the UK and the Blu-ray optical disc format.

Future developments could improve compression further,[57] although widely utilised standards take time to develop and higher levels of compression may be more susceptible to transmission errors. In addition, whilst very large cheap memories will partially substitute for the need to move existing content over broadband and wireless connections, the amount of new and real time content is growing rapidly, particularly user generated content.

We consider wireless in some detail in Appendix B and conclude that whilst it is an important complement to fibre as a means of delivering high speeds within the home and potentially as a means of improving broadband coverage in rural areas with 3G utilising 900/1800 MHz spectrum and satellite delivery, it is not likely to be a technically and commercially feasible substitute for fibre access for many users. The capability of wireless will however continue to improve, and some users will find wireless services adequate and drop or not opt for a fixed line, either copper or fibre.

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[54] Satellite is included in the "other" category in Ofcom data which in H1 2007 accounted for 0.1 per cent of residential and SME broadband connections. Ofcom. 2007. "The Communications Market 2007." Page 262. http://www.ofcom.org.uk/research/cm/cmr07/telecoms/telecoms.pdf

[55] May 2008. http://www.freesat.co.uk/home.php

[56] Ofcom. April 2008. "Digital television – enabling new services." http://www.ofcom.org.uk/consult/condocs/dttfuture/statement/statement.pdf

[57] For example, various proprietary standards exist: http://www.codecsys.com/ and http://www.brin.com/newsroom/2008/04102008a.html

A key element of our counterfactual is the performance of copper based DSL given its wide availability and share of the broadband market. Table 4-1 summarises the counterfactual access line speeds for copper based DSL – assuming technology currently in existence has been deployed.

Table 4-1: Access line speed for ADSL and ADSL2+

	Upstream	Downstream	
	ADSL & ADSL2+	ADSL	ADSL2+
Maximum access line speed	0.8 Mbps	8 Mbps	24 Mbps
Median line speed	0.7 Mbps	5 Mbps	9-10 Mbps
Minimum line speed available to 90 per cent of users	NA	2 Mbps	2.5 Mbps

Note: The table shows national average estimates and estimated performance would vary region-by-region depending on the distribution of line lengths.

Actual performance may be lower when account is taken of factors such as home line noise and wiring, home modem performance and transport protocol overheads. Together these factors could reduce performance by up to 25 per cent (see Figure A.2 in Appendix A). However, there is also a range of measures that could improve performance.[58] Whilst home line noise and wiring would also be a constraint on fibre service, modem performance and transport protocol overheads should be much less of a constraint.

Access line speeds over existing line lengths might improve further in future, though there are constraints in terms of the underlying physics on what can be achieved. Ofcom research on the theoretical limits of copper in the last mile concluded that the upper bound data rate for 50 per cent of lines in the UK would be 22 Mbps or more (shared in both directions compared to a median for ADSL2+ of 10-11 Mbps considering downstream and upstream).[59] Much higher speeds could be achieved over short line lengths (over 100 Mbps), whilst theoretically achievable data rates over longer lines are not much higher than those currently commercially available.

Overall the key elements of our counterfactual are the upgrade of cable utilising DOCSIS3.0 technology to deliver 50Mbps downstream, the upgrade of terrestrial wireless utilising new standards such as 3.5G including HSDPA and HSPA and WiFi 802.11n, and no significant increase in speed for a significant number of end users over existing copper line lengths beyond ADSL2+.

We note that some of the benefits that we attribute to next generation broadband in Section 5 may be released via development under the counterfactual, including upgrades to copper, cable, and wireless access and other technologies such as compression. It is difficult to quantify the precise incremental benefits of next generation broadband given uncertainty over developments under the counterfactual. However, we note that many of the longer term benefits of next generation broadband depend on high and consistent speed in both directions – an attribute that is only likely to be available to a limited extent under the counterfactual.

[58] March 2008. "BT Wholesale demonstrate further improvements with 21CN." http://www.samknows.com/broadband/news/bt-wholesale-demonstrate-further-improvements-with-21cn-350.html

[59] Ofcom. May 2008. "Tomorrow's wireless world." Page 57. http://www.ofcom.org.uk/research/technology/overview/randd0708/randd0708.pdf

4.3 Wait and see (late versus early deployment)

The option to invest in future (or never) is left open if investment does not proceed immediately, whereas if investment does proceed much of the cost will be irreversibly sunk (non-recoverable for alternative uses). Where the value of investing is expected to rise over time, or the return on investment is uncertain, this asymmetry in terms of options can create a value to waiting. This value should be considered explicitly in appraisal, and therefore differs from "passive" consideration of the counterfactual.

In particular, uncertainty over costs, demand and willingness to pay for FTTH and FTTC may be materially reduced within 18 months or so, thereby reducing the option value associated with waiting by around 2010.

In addition, as broadband penetration grows, applications develop and consumers' incomes and expectations rise, the anticipated payoff from next generation broadband investment will increase. Growth in value over time can be grounds for investing only when investment is expected to earn a premium relative to a static analysis, which may imply deferring investment – for a time.

4.4 Fibre to the Cabinet (FTTC)

Fibre can be extended part way to the customer premise with active electronics installed at the street level and existing copper utilised to reach the customer premise. This would offer higher speeds than existing broadband, but variability in performance would remain and operating costs might increase rather than decrease in overlay modes of deployment. FTTC offers scope for improved performance at lower capital cost than FTTH, however, there is a risk that the useful life of these assets would be curtailed if it was subsequently decided to move to FTTH.

The potential capability of FTTC in the UK is being evaluated by Openreach. Actual performance is difficult to judge in advance since VDSL2, which would be deployed over copper from street cabinets to the home, is more sensitive to factors such as radio noise and modem set up (which would require a technician to visit people's homes to install and tune their modem to achieve the full performance potential of VDSL2). Table 4-2 provides estimates of the capability of FTTC utilising VDSL2:

Table 4-2: Indicative access line speed of FTTC utilising VDSL2

	Upstream	Downstream
Headline speed capability	Around 20 Mbps	Around 50 Mbps
Median speed	Around 10	22-30
Minimum speed available to 90 per cent of users	NA	NA

Source: George Williamson. December 2007. http://conferences.theiet.org/nextgeneration/index.htm
Note: performance estimates assume VDSL2 replaces DSL, if the two are run in parallel the performance of VDSL2 could be lower.[60]

The OECD also discusses the capability of FTTC and VDSL2, and notes that in order to deliver around 30 Mbps up and 50 Mbps down, the cabinet/switch has to be around 450m away from the

[60] Light Reading. May 2006. "VDSL2". http://www.lightreading.com/document.asp?doc_id=93103&print=true

customer.[61] The theoretical upper limit for FTTC – assessed for Ofcom on the same basis as the theoretical potential for ADSL considered earlier – is 500 Mbps or more for 50 per cent of customers.

FTTC would be quicker and cheaper to deploy than FTTH. We assume that FTTC could reach a high level of coverage, over 80 per cent, in less than five years. FTTC might also be utilised to provide broadband service in areas where existing copper line lengths make current broadband infeasible (so called not spots). Assuming investment started in 2010, an FTTC deployment might be complete by around 2015.

4.5 Fibre to the Home (FTTH)

Fibre could be taken all the way to the customer premise on a point-to-point basis or using passive optical network technology (PON or GPON). For simplicity and clarity in our modelling of costs, performance and benefits we assume GPON architecture – no inference regarding the preferred technology should be taken from this. We note that point-to-point fibre has been deployed in some countries. In comparison with GPON, point-to-point fibre may provide performance advantages but it is likely to be more expensive.[62] [63]

Point-to-point fibre also provides more potential for competition via unbundling. However, we assume that a fit for purpose access product will be provided on an equivalence of inputs basis irrespective of the technology choice (the specification for an Ethernet bitstream product over fibre is subject to ongoing industry discussion).

FTTH currently offers end users performance of around 50-100 Mbps download and 20 Mbps upload in commercial deployments in addition to capacity for television services, with potential to increase capacity in future. The capability of GPON FTTH is summarised in **Table 4-3**.

Table 4-3: Performance of FTTH utilising GPON (in addition to TV capacity over a single fibre)

	Upstream	Downstream
Current GPON fibre	1,200 Mbps	2,400 Mbps
Uncontended per premise with 32 way split	37.5 Mbps	75 Mbps
Next generation PON with wave division multiplexing (WDM)	4 to 32 fold improvement in speed and potential extension of reach from 20 km to 100 km. [64]	

Note: the above speeds are in addition to the capability to offer a TV service on a separate channel over GPON

Whilst FTTH is proceeding for some new build, an overlay or replacement FTTH investment programme would take perhaps 10 years to reach a coverage level of around 80 per cent (beyond which the costs might be prohibitive). Assuming investment started in 2010, FTTH coverage in terms

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[61] OECD. 3 April 2008. "Developments in fibre technologies and investment." Page 16. http://www.oecd.org/dataoecd/49/8/40390735.pdf

[62] The OECD provides some discussion of PON versus point-to-point fibre. OECD. 3 April 2008. "Developments in fibre technologies and investment." http://www.oecd.org/dataoecd/49/8/40390735.pdf

[63] Openreach. October 2007. "Fibre products design review working group – technology session." Page 13. http://www.openreach.co.uk/orpg/products/nga/downloads/Fibre_Products_Industry_Workshop_Slides_4th_Oct_2007.ppt

[64] Peach and Goderis. Autumn 2007. "PON standard aims for 10 Gbp/s." *FibreSystems Europe.* http://www.ftthcouncil.eu/documents/articles/FibreSystems_EuropeDannyGOderis.PDF

of homes passed for the existing customer base would therefore reach 40 per cent by 2015 and 80 per cent by 2020. It is important to keep these time frames in mind when considering the availability of applications that would benefit from FTTH, and demand and willingness to pay.

4.6 Overview of scenarios

There are various paths for the development of fibre, involving the following options and interdependencies:

- The wait and see option is valuable given the uncertainty involved and the risk of investing in an option that proves either excessively costly or short sighted.
- FTTC, which has lower capital costs and could be deployed more quickly than FTTH; but has less capability and no clear upgrade path (other than moving to FTTH). 80 per cent availability by 2015.
- FTTH with the option to upgrade to higher speed PON in future. 80 per cent availability by 2020.

In practice, a next generation broadband deployment may include a mixture of wait and see and FTTH and FTTC. The options are not mutually exclusive.

5 Cost-benefit estimation

"As to Bell's talking telegraph, it only creates interest in scientific circles... its commercial value will be limited." Elisha Gray

5.1 Introduction

In this section we develop estimates of cost and benefit for the different categories set out in the framework in Section 3, these are: private costs (of fibre deployment); private benefits; wider economic costs and benefits; and wider social costs and benefits. We then discuss the incremental benefits of different levels of network coverage and incremental benefits of FTTH over FTTC.

We do not calculate an overall net present value, but provide a mix of quantitative and qualitative analysis of the various impacts to identify:

- whether they are positive or negative (i.e. a cost or a benefit)
- their potential scale
- their potential timing

The evidence base for the different categories of cost and benefit is variable. In some cases, whether the impact is positive or negative (i.e. whether it is a cost or a benefit) is uncertain and may depend on other factors or policy agendas (for example, whether greenhouse gas policy objectives are achieved primarily through a carbon charge or other instruments that offer less scope for next generation broadband to contribute to emissions reduction).

In considering the value of next generation broadband we consider the incremental value of wide spread availability and take-up against a counterfactual where there is some, but more limited investment in next generation broadband (i.e. fibre deployment in green field sites beginning with the Ebbsfleet development in Kent in Autumn 2008) alongside progressive upgrades to existing copper, cable and wireless networks.

To the extent that upgrades to copper, cable and wireless and other technologies such as compression under the counterfactual generate benefits that we attribute to fibre, then our incremental benefit estimates may be overstated. It is difficult to quantify the precise incremental benefits of next generation broadband given uncertainty over developments under the counterfactual. However, we note that many of the longer term benefits of next generation broadband depend on high and consistent speed in both directions – an attribute that is only likely to be available to a limited extent under the counterfactual.

5.2 Methodology for estimating costs and benefits

In assessing costs and benefits we consider the incremental impact of next generation broadband, and focus in particular on FTTH (GPON). We have done this simply because there is greater understanding about its capabilities (information on the likely speed distribution for FTTC for the UK was not available).

In calculating costs and benefits we assume wide area coverage of 80 per cent of households and small enterprises (approximately the urban population of the UK, which also roughly corresponds to the footprint of unbundled local exchanges in the UK). Based on 25 million households and roughly 1.2 million small (0-50 employees) enterprises with employees, this gives a total of 26.2 million premises. Assuming the availability of next generation broadband to 80 per cent of premises the total number of premises would be approximately 21 million.

In relation to network deployment costs, a number of estimates are available. These include estimates for the US (Appendix C), estimates published by the OECD[65] and estimates for FTTC in relation to Ireland and Australia. The obvious disadvantage of these cost estimates is that they are not UK specific.

However, soundly based UK estimates were not available to us. Further, where investment in next generation broadband utilises existing assets such as ducts and poles, a detailed knowledge of existing infrastructure would be required to develop more specific and realistic cost estimates.

The cost estimates we provide are therefore necessarily indicative. We note that as part of the Government review of barriers to next generation broadband the Broadband Stakeholder Group is undertaking further research on the costs of deployment of FTTH and FTTC in the UK to be published in Q3, 2008.[66] We also note that the range of cost estimates we utilise is wider than that in the Broadband Stakeholder Group publication "Pipe Dreams?"

In relation to benefits, we focus on overall potential economic welfare gains. These gains would be distributed throughout the new value chains created by next generation broadband and not all of the benefits would necessarily be captured by investors or end users.

Finally, we note that some benefits, in particular those related to new applications and services, would take time to develop as next generation broadband is rolled out, the applications mature and network effects enable their full value to be exploited (where network effects apply). These lag effects mean that some categories of benefit might not therefore reach their potential until FTTH rollout is widespread, perhaps around 2020. Other categories of benefit would be realised quickly, in particular the opportunity to do what people do now more productively over next generation broadband.

5.3 Wait and see (late versus early deployment)

The option to wait exists alongside the option to invest now. Waiting may be valuable if net benefits are expected to rise over time or if some existing uncertainties over costs and benefits might be resolved – which might then lead to a decision to invest or wait longer. Therefore, the investment decision rule is not whether the net present value is greater than zero, but whether it is greater than the value of waiting. This also leads us to reframe the question "what is the cost of delay?", as the value of delay may be positive in the short term even if the expected value of the investment is positive.

We consider that there is a large option value (i.e. benefit) attached to waiting over the short term. In the medium term, this (option) value might decline as constraints on realising value are removed and

[65] OECD. 3 April 2008. "Developments in fibre technologies and investment." http://www.oecd.org/dataoecd/49/8/40390735.pdf

[66] BERR. 22 February 2008. "Next generation networks – broadband review." http://www.berr.gov.uk/sectors/telecoms/telecomsbroadband/page10034.html

as some existing uncertainty over costs and benefits is resolved. In relation to the question regarding the costs of delay, our analysis points to the possibility that delay would be beneficial in short term and costly in the medium to long term.

A level of uncertainty will always exist, however some aspects of uncertainty may be greatly reduced in the near term, reducing the option value associated with waiting before investing or deciding which technology is optimal and therefore improving the case for investment. For example:

- Trials of FTTC and further modelling should help reduce uncertainty over its likely performance in a UK deployment, with improved information anticipated during 2008.
- UK regulatory policy – and potentially the position of the European Commission – including the intended approach to regulation of next generation broadband and the approach to the transition to next generation broadband should be clearer over the next two years.
- The availability of a faster longer range WiFi standard (802.11n) from 2009 may reduce problems associated with within home distribution of next generation broadband, long range GPON may lower costs, whilst progressive improvements in servers, core networks and the installed base of PCs will increase the magnitude and bring forward the timing of benefits of next generation broadband deployment.
- Information about willingness to pay and take-up in relation to next generation broadband will expand considerably by 2010 as more data becomes available from deployments of FTTH and FTTC in the UK and in other countries.

The existence of an option value associated with waiting and learning means that the cost of delay may not be as pronounced – or there may be a benefit – as it would be if the static cost of delay alone were considered (assuming the expected overall value of next generation broadband today is positive).

We consider that there is a large option value attached to waiting over the next 18 months or so. Beyond 2010, option values are likely to reduce, though next generation broadband may still need to earn a premium over normal returns to justify immediate investment if capital costs continue to fall. There may also be value attached to the information that next generation broadband trials deliver in terms of costs and benefits, thereby contributing to a reduction in the option premium due to uncertainty, ahead of a large scale deployment.

5.4 Private costs

We consider two scenarios – the deployment of FTTH and FTTC to 80 per cent of UK homes and premises.[67] We note that in practice an actual deployment is likely to involve a mix of FTTH and FTTC. We then discuss the implications of a complete replacement of the existing copper network.

We note that the Broadband Stakeholder Group is currently undertaking further work to develop a specific cost model for the UK (which should be available in Q3 2008). Our figures are based on data available from next generation access deployments in other countries (mainly the United States) and

[67] This is approximately the proportion of UK households located in towns and cities and also roughly corresponds with the footprint of unbundled local telephone exchanges in the UK.

should be considered indicative at best. The details of our cost estimates are provided in Appendix E. The estimates for the US that we utilise are summarised in Table 5-1.

Table 5-1: Costs for FTTH and FTTC (US$)

	AT&T[68] FTTC	Verizon FTTH[69]			
	2006	**August 2006**	**Year end goal 2006**	**2008 Sanford Bernstein[70]**	**2010 expected by Verizon**
Cost per home passed	300	873	850	817	700
Cost per home connected	550	933	880	718	650

Note: The Verizon FTTH cost estimates include the cost to pass a home, connect a home, install customer premise equipment, including a wireless router, and ensure the service is working satisfactorily i.e. it is the cost to provision a retail service. They do not include the costs of enhancing other elements of the network to support an enhanced access network.

5.4.1 FTTC

Based on US and other estimates we assume FTTC costs, including the costs of service provision (installing and setting up new modems etc) are in the indicative range £250-£400 per household. The total cost of deploying FTTC with 80 per cent coverage would be at least £5.3 billion based on this range per household.

We do not explicitly consider any change in overall operating costs in relation to FTTC. Any change in operating costs would depend on the details of deployment, for example, whether local exchanges are maintained under FTTC.

5.4.2 FTTH overlaying the copper network

Based on Verizon's cost estimates for 2008 for FTTH, we assume an up-front capital cost of £409 per home passed and £359 per home connected based on 2008 costs (assuming an US$:£ exchange rate 2:1). For FTTH costs per customer are highly dependent upon the penetration levels (the percentage of households and businesses that actually take-up the service), ranging from £2,402 per household for penetration levels of 20 per cent to £768 for a penetration level of 100 per cent. Overall costs are of course lower for lower penetration levels.

We do not explicitly consider any change in overall operating costs in relation to FTTH overlay scenarios. Any change in operating costs would depend on the details of deployment, for example, whether copper lines are maintained for those who opt for FTTH.

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[68] Pers comm. Richard Dineen. January 2008. HSBC. Also provided numbers for Verizon consistent with public figures shown.

[69] With exception of Sanford Berstein column: NetworkWorld. September 2006. "Verizon provides FiOS update." http://www.networkworld.com/news/2006/092706-verizon-fios.html?page=2

[70] Sanford Berstein. January 2008. "Economics of FiOS make little sense for Verizon." http://www.multichannel.com/article/CA6524100.html

5.4.3 FTTH with replacement of copper

As an alternative to FTTH overlay, FTTH could be deployed as a replacement for the copper telephony broadband network with the explicit aim of 100 per cent connection of premises to fibre and copper network shutdown location by location as fibre is rolled out (100 per cent connection is required to maintain service with copper network shutdown). Whilst additional costs would be incurred in migrating services over to fibre, the need to operate one rather than two networks would result in operating cost savings over time.

We note that there would also be potential gains from the sale of copper and land and buildings currently utilised for exchange buildings. Together the value of copper, land and buildings might realise up to £1 billion during the investment phase, which could be netted off the investment cost. We treat this as part of the cost savings i.e. we do not treat it as additional.

Given the uncertainty over operating cost savings and the fact that we do not account for the cost of achieving such savings, we consider assumed savings in the range 30 to 50 per cent with a minimal lag in achieving savings. Under these assumptions the cost of FTTH replacement might fall from £768 per household to £572 or £442 respectively, or a total cost of £12 billion to £9.3 billion for 80 per cent coverage and 100 per cent take up. We do not allow for migration costs. However, overall savings, including proceeds from the sale of copper and land and buildings, could potentially be greater than the above assumptions and net lifecycle costs correspondingly lower.

Achieving this outcome would involve a number of difficult engineering, commercial, regulatory and policy challenges that would need to be overcome. Box 5-1 sets out some of these challenges.

Box 5-1: Policy, regulatory and commercial challenges of a complete copper replacement

With appropriate planning and regulatory and policy support copper replacement could occur locally as FTTH is rolled out. This would raise the cost of rollout since all homes would need to be connected to provide continuity of service when copper is shut down. However, operating only the fibre network would significantly lower operating costs.

Copper replacement would not be straightforward. The competitive provision of the current generation of broadband services is dependent upon competitive operators having access to the copper network from the exchange. Transitional arrangements would need to be in place for service providers including fit for purpose wholesale access products over FTTH to ensure effective competition in the provision of broadband services over these new networks. It should also be noted that the copper network is a powered network and supports basic telephony as well as broadband and other services such as traffic lights. Entry to every household would be required to obtain power for the optical terminating equipment with a fibre replacement strategy.[71] Expectations of universal telephony service are enshrined in USO obligations. Those customers who simply wanted to continue with telephony service might reasonably expect to continue to pay a price in line with historical charges. The replacement of copper would therefore require significant changes to the policy-regulatory framework.

No single example of network switchover from other sectors is completely analogous – though there are parallels. Analogue mobile switch off was achieved voluntarily by industry, but penetration was low, there were no obligations and remaining customers were given new handsets that would work on digital networks. Copper replacement is more challenging, and has more in common with the move to North Sea gas or digital switchover

[71] Back-up battery power to support voice services in the event of power outage is also likely to be provided with FTTH (in the US Verizon support voice service with battery power, but not broadband, in the event of power outage).

(DSO) in the broadcasting sector – which is being phased in regionally from October 2007 to 2012, and required significant policy coordination, an information campaign and targeted support for some. Copper replacement is however easier in some respects since regional and international coordination is not required. However, notice might ultimately have to be given to customers who do not opt to allow connection of fibre to the premise equipment.

An approach to service pricing would also need to be found that was efficient and equitable if all households (within our assumed 80 per cent footprint) were converted to FTTH, but not all households demanded next generation broadband (or even first generation broadband). One approach to this problem – termed "anchor product" regulation – would be to charge customers existing prices for existing voice and broadband service capabilities (over copper) emulated over fibre, and only charge a premium for those customers who demanded next generation broadband capability.[72]

The incremental operating costs of fibre under a copper replacement strategy are taken into account in the savings assumption of 30-50 per cent with copper replacement (otherwise the saving would be 100 per cent).

5.4.4 Consumer costs

Householders might need to be at home for half a day during installation, and whilst the value of leisure or work time foregone would vary considerably, a rough proxy might be £25 per hour for 3 hours for 50 per cent of households – with others experiencing limited costs (we assume that the cost is the working time rate rather than the leisure rate here).[73] Householders' time might therefore add an average of £37.50 to installation costs – a modest amount compared to the capital costs involved. For 80 per cent network coverage the value is £800 million.

The full value would apply to FTTH with replacement of copper, with smaller values applying to FTTH overlay depending on take-up and a much smaller value applying to FTTC. We also note that where consumer time required for installation is voluntary, it is a private cost. However, to the extent consumers who would not voluntarily adopt next generation broadband are required to allow installation of terminating equipment to maintain existing telephony and/or broadband service the costs are an externality.

5.4.5 Conclusion regarding costs assumptions

Our cost estimates are indicative only, since they are based on data available from next generation deployments in other countries (mainly the United States). Based on these, we also calculate the "rental equivalent" costs of FTTC, FTTH (for 100 per cent take-up) and FTTH with copper replacement and operating cost savings of 30 and 50 per cent (by spreading FTTC costs over 5 years and FTTH costs over 10 years, taking an NPV and calculating the equivalent in perpetuity annuity assuming a 10 per cent discount rate).

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[72] Brian Williamson. July 2007. "New regulatory approaches to next generation access." http://www.broadbanduk.org/component/option,com_docman/task,doc_view/gid,944/

[73] http://www.webtag.org.uk/webdocuments/3_Expert/5_Economy_Objective/3.5.6.htm

The purpose of calculating rental equivalents is to allow some level of comparison with potential benefits, though noting that some benefits – particularly those involving transformations of value chains and services – might only be realised with a significant lag relative to costs.

Table 5-2 summarises the estimates for FTTC, and FTTH with and without copper replacement.

Table 5-2: Cost estimates assuming 80 per cent network coverage

	Per premise	Total	Annual equivalent
FTTC (100% "take-up")	£250	£5.3 billion	£380 million
FTTH overlay			
100% take-up	£768	£16.1 billion	£980 million
50% take-up	£1,176	£12.3 billion	
20% take-up	£2,402	£10.1 billion	
FTTH copper replacement (100 % "take-up")			
Lifecycle cost with 30% opex savings	£572	£12 billion	£740 million
Lifecycle cost with 50% opex savings	£442	£9.3 billion	£570 million
Consumer time required during transition		£800 million	£49 million

Note: Under FTTC and FTTH with copper replacement take-up is 100 per cent because it is assumed that the new service replaces existing services over local loops.

We assume that total costs will be in the range of £5 billion (FTTC with 80 per cent coverage) to £16 billion (FTTH to 80 per cent coverage with 100 per cent take up). In practice actual deployment may involve a mix of the two technologies so actual costs might be somewhere within this range. However, we note that these estimates should not be taken as representing lower or upper bounds. The costs of FTTH depend on take-up, since connection costs are substantial, for example, overall costs for 50 per cent take-up are estimated at £12 billion.

For FTTH with copper replacement the lifecycle cost range is £9.3 to £12 billion for operating cost savings of 50 and 30 per cent respectively – assuming savings can be made quickly. In effect we are allowing for incremental operating costs of FTTH with copper replacement in this calculation. Overall savings, including proceeds from the sale of copper and land and buildings, could potentially be greater than the above assumptions and net lifecycle costs correspondingly lower.

We do not explicitly consider any change in overall operating costs in relation to FTTC or FTTH overlay scenarios. Any change in operating costs would depend on the details of deployment, for example, whether local exchanges are maintained under FTTC or whether copper lines are maintained for those who opt for FTTH. The incremental operating costs of fibre under a copper replacement strategy are taken into account in the savings assumption of 30-50 per cent with copper replacement (otherwise the saving would be 100 per cent).

5.5 Private benefits

We consider two approaches to valuation:

- Looking at revealed behaviour in terms of next generation broadband take-up, customer switching behaviour where fibre is offered and a choice of bandwidth and price points.
- Directly considering the potential incremental benefits of next generation broadband in terms of time savings, doing more in relation to existing services and doing new things.

The first approach is more relevant to the commercial case for next generation broadband investment, whilst the second approach aims to get at underlying value creation – regardless of whether this can be captured by investors. Nevertheless, revealed information on willingness to pay can help inform estimates of private economic benefits (though since consumers will retain some consumer surplus revealed behaviour provides a lower bound on willingness to pay).

Estimates have been made of the future (unconstrained) demand for bandwidth which indicate that demand could soon exceed the capability of copper over existing line lengths for a significant proportion of consumers.[74] However, we are seeking to value potential incremental demand for next generation broadband, and are therefore interested in a future-supply equilibrium factoring in users willingness to pay for additional bandwidth.

Where consumers are offered choices in terms of bandwidth and price their revealed behaviour in terms of switching and take-up is an indicator of current willingness to pay. The switch from dial up to broadband indicates a preference for always on (or quick on), simultaneous availability of voice and higher connection speeds. Initially consumers had to pay a premium for broadband, though with the availability of bundles in which broadband is offered "free" some consumers may view broadband as having no premium. Nevertheless, many consumers do pay a premium for broadband compared to dial up (or no internet at all).

Cable and some DSL plans in the UK offer price differentiation by bandwidth. For example, Virgin Media differentiate their pricing by bandwidth offered on an 'up to' basis with 8Mbps DSL in non-cable areas for £17.99 and cable service available at speeds of 2 Mbps, 4 Mbps, 20 Mbps and 50 Mbps (on a trial basis) at prices of £18, £25, £35 and £45 per month respectively (the 2 and 4 Mbps plans are to be upgraded to 10 Mbps).[75] In relation to next generation broadband, Openreach propose a differentiated service offering for new build fibre with higher bandwidth and assured bandwidth, both up and down, charged at a premium. **Table 5-3** sets out the proposed wholesale offering.[76]

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[74] BSG. 2007. "Pipe dreams?" Figure 9.
George Williamson. December 2007. http://conferences.theiet.org/nextgeneration/index.htm

[75] http://pressoffice.virginmedia.com/phoenix.zhtml?c=205406&p=irol-newsArticle&ID=1100403&highlight=

[76] Openreach. 15 May 2008. "Future access forum." Page 39.
http://www.openreach.co.uk/orpg/products/nga/downloads/Main_slide_deck_final.pdf

Table 5-3: Proposed access pricing for Ebbsfleet FTTH

	Wholesale price per month (excl VAT)
Up to 100 Mbps downstream; assured 10 Mbps downstream and 2 Mbps upstream	£24.50
Up to 30 Mbps downstream; assured 10 Mbps downstream and 2 Mbps upstream	£19.50
10 Mbps assured downstream and 2 Mbps upstream	£7.50
Up to 2.5 Mbps downstream, 500 kbps assured symmetric	£4.60
135 kbps assured symmetric	£6.90

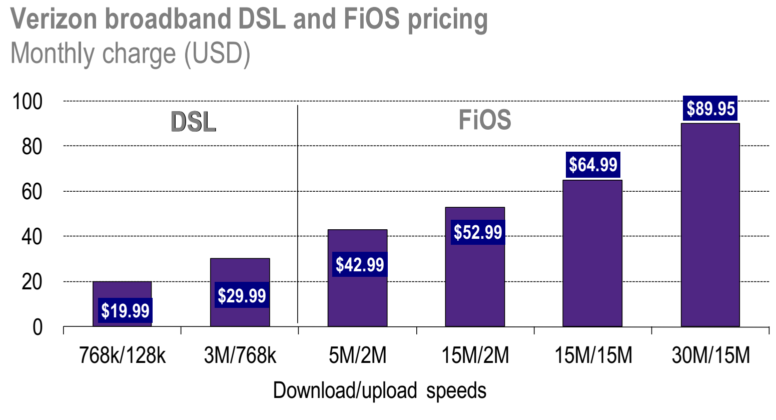
Note: The above prices are not retail prices and do not include connection charges. Openreach propose an "introductory offer" applicable until 31 March 2010 for new build sites of zero connection and rental prices with some restrictions for a single service provider and excluding handover port and connectivity link charges.

Ebbsfleet provides an opportunity to learn about end user willingness to pay for bandwidth, though willingness to pay for significantly higher upload speeds would remain untested under current plans.

Outside the UK, experience in the US is perhaps the most informative since next generation broadband is offered on a commercial and unregulated basis, and some information is available regarding consumer behaviour. Experience in countries such as Korea and Japan is less informative since consumers do not necessarily pay any premium for higher speed (perhaps as a matter of national policy).[77]

Pricing (see Figure 5-1 below for fibre and copper pricing) and take-up of Verizon's FiOS FTTH broadband service in the US provides evidence of willingness to pay for higher upload and download speeds (we note that there is significant FiOS take-up without bundled TV). Further details are provided in Appendix C.

Figure 5-1



Source: Plum Consulting. www22.verizon.com. Pricing for one-year contracts.

We note the willingness to pay for next generation broadband could be expected to grow over time as incomes grow, and people make more demanding use of their broadband connections. This

[77] We also note, in relation to Korea, that as of May 2007 most consumers of Korea Telecom who had 45 per cent of the broadband market were on "Lite" plans offering speeds of 4 Mbps down and either 640 kbps or 4 Mbps up. See Scott Wallsten. June 2007. "Everything You Hear about Broadband in the U.S. is Wrong." http://www.pff.org/issues-pubs/pops/pop14.13wallstenOECDbroadband.pdf

approach to estimating the private value of next generation broadband could be developed in future once more experience is available.

The alternative approach is to estimate the value of the attributes of next generation broadband, and the applications it would support, directly. In Section 3 the following broad categories of benefit were identified, namely:

- Saving time doing what people do now, but at the same time and in less time – thereby enabling higher productivity and/or more time for alternative forms of leisure.
- Doing more of the existing things where next generation broadband improves the experience most – particularly rich content sharing, viewing and forms of collaboration.
- Doing new things involving transformations of the way we live, work and create and distribute value.

In terms of potential transformations, two stand out (we can see them in outline form today). First, video distribution and two-way HD video communication. Second, a progressive move to "cloud" computing involving storage, computation and software applications available over the internet.

5.5.1 Saving time

It is reasonable to regard the time that people spend online as valuable and to value it – just as one would value time in evaluating a new transport project that could reduce journey times. In fact, the value of time is the only cost of using the internet where usage charges at the margin do not apply (as opposed to monthly subscription charges).

This category of benefits would have the most immediate impact, since we do not have to wait for new applications and services for the benefits to build up over time.

By considering time spent using the internet, Goolsbee and Klenow (2006) estimate the value of internet access at around 2-3 per cent of income, substantially more than expenditure on internet access.[78]

There are a number of estimates of the amount of time people spend online, and we know that it is growing. We also know that one of the reasons people go online is to save time by using the internet to shop, find information or organise activities efficiently – if they are using the internet to save time the less time it takes the better. Whilst consumers may be able to do other things when data is uploading or downloading, there may be insufficient time to effectively switch tasks, access may be slow while a background task is performed and multi-tasking may interfere with other users utilising streamed services. It therefore seems reasonable to assume that data transfer limitations impose significant costs on users.

Estimates of time online show that UK citizens are the most active online community in Europe:

- Internet use by those aged 14+ was 11 hours at home and 7 hours at school/work per week in the UK.[79]

[78] Goolsbee and Klenow. January 2006. "Valuing consumer products by the time spent using them: an application to the internet." NBER Working Paper No. 11995. http://siepr.stanford.edu/papers/pdf/05-10.pdf

[79] Oxford Internet Institute. 2007. "The Internet in Britain 2007." http://www.oii.ox.ac.uk/research/oxis/OxIS2007_Report.pdf

- The UK has the most active online population in Europe, with the average 15+ user (a population of 31 million users) spending 34.4 hours online per month at home or at work compared to an average of 24 hours in Europe and 31.4 hours in the US.[80]

Further, there is a general shift in internet usage towards online activities that are more demanding in terms of available bandwidth where existing broadband bandwidth is more likely to result in delays, in particular upstream content sharing, rich content consumption and simultaneous use within a household. In some instances delays will be incurred, in others people simply will not do the things they would like to do if their broadband connection was faster and less error prone (in particular for streamed video and two way video). Here we focus on the value of time savings assuming usage of the internet is unchanged i.e. people do the same things in less time (expansion in use and doing new things are considered in subsequent sections).

Estimates of the value of leisure and working time are provided in Transport Analysis Guidance published by the Department for Transport.[81] In 2002 non-working time was valued at £4.46 per hour, whilst average working time was valued at £22.63 per hour. Assuming the value of time grows in proportion to income, and that income growth averages 2 per cent per annum real and around 4 per cent nominal, non-working and working time would be valued at around £5.50 and £29 respectively in 2008.

Based on the amount of time people spend online and a value of time of £5.50 per hour (a conservative assumption given that some of the time is work related), the total opportunity cost of time online is around £78 billion per annum. This dwarfs money expenditure on broadband of around £3 billion per annum (much of which in any case relates to access rather than usage).[82]

If next generation broadband enabled internet users to save, say, 3 per cent of their time online (purely an assumption), the value would be around £2.3 billion per annum. For 80 per cent network coverage the value is £1.8 billion per annum. Assuming usage weighted take-up of high speed packages of 50 per cent, the estimate is £0.9 billion per annum.

5.5.2 Doing more of some existing things

The constraints of existing broadband speeds are most apparent when upload times are considered, but are also increasingly apparent as consumers move to download large video files. The following examples compare the time required with 20 Mbps fibre upload speeds versus 768 kbps upload speeds for copper (the limit for ADSL2+).

- A consumer could upload a 250 megabyte (MB) file of 200 photos in about 90 seconds, compared with about 47 minutes over a 768 kilobits per second (kbps) upstream connection.
- A 500 MB file, such as 400 digital photos or a medical imaging data set could upload in less than four minutes, compared with about 90 minutes over a 768 kbps connection.

[80] comScore. June 2007. http://www.comscore.com/press/release.asp?press=1459

[81] http://www.webtag.org.uk/webdocuments/3_Expert/5_Economy_Objective/3.5.6.htm

[82] Ofcom. 2007. "The communications market 2007." Figure 4.45. http://www.ofcom.org.uk/research/cm/cmr07/cm07_print/cm07_3.pdf

- A 3 gigabyte (GB) file, such as a one-hour family video shot with a high-definition video camera, can be uploaded in around 20 minutes, compared with more than nine hours with 768 kbps upstream.

There is clear evidence of growth in video sharing, for example for the US:

> *"22% of Americans shoot their own videos and that 14% of them post some of that video online… more than triple the percentage of video takers who said they had posted videos when we asked a similar question in a survey taken February-April in 2006".*[83]

In the UK photo and video sharing, and demand for services such as iPlayer, point to a significant shift in behaviour as individuals become more active participants, and as they increasingly produce, share and manipulate visual media. Relative to fibre, it is almost certain that existing broadband speeds act as a constraint on this activity, particularly in relation to content sharing.

It is difficult to value the expanded possibilities that faster connections would allow. The expansion of, for example, PC use that falling prices and/or improving performance have enabled has been estimated – with PCs now estimated to contribute benefits of 4 per cent of personal consumption expenditure (PCs have an expenditure share of 0.6 per cent in the US).[84]

One approach to valuing the benefits of doing more if next generation broadband were available would be to consider the time taken to utilise different applications to perform different tasks as the price of internet access, and to calculate how this price and therefore demand would change if less time was required. Another approach is to calibrate an aggregate demand curve given the current "price" of access (in terms of time foregone), and then estimate the gain at the lower "price" reflecting faster access.

An example of an application that might be expected to expand considerably with much faster upload speeds would be online back-up – both for SMEs and households. Increasing quantities of valuable information is stored on PCs, for example, digital photos and videos. Online backup will remain limited given connection speeds of around 0.7 Mbps – a 20 Mbps upload speed would represent an almost 30 fold increase in speed. Whilst local back-up using a separate hard drive is feasible, it does not provide the same level of security as offsite back-up (which currently exists as a service). If fast, reliable and secure online back-up were worth around £50 per annum – roughly what people pay for virus protection – for 10 million next generation broadband households (assuming 50 per cent next generation broadband penetration across 20 million broadband households), the value would be £500 million per annum. Subtracting user charges of around $5 (£2.50) per computer per month for online back-up[85] would leave a surplus of around £200 million per annum. For 80 per cent network coverage the value is £170 million per annum.

Another approach, for the business market, is to consider existing and potential demand for fibre links based on current prices for point-to-point fibre and likely prices for a commercial service over GPON. There are currently around 120,000 point to point fibre connections. A 34 Mbps leased line might cost £20,000 per annum.[86] Bonded copper pair products are also available offering intermediate

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[83] Pew Internet and American Life Project. January 2008. http://www.pewinternet.org/pdfs/Pew_Videosharing_memo_Jan08.pdf

[84] Greenwood and Kopecky. September 2007. "Measuring the welfare gain from personal computers." http://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID1089015_code80708.pdf?abstractid=1014921&mirid=1

[85] For example, the Mozi online back up service costs $4.95 per month. http://mozy.com/

[86] Ofcom. January 2008. "Business connectivity market review." http://www.ofcom.org.uk/consult/condocs/bcmr/bcmr_pt1.pdf

symmetric speeds. For example, 2 Mbps symmetric lines are available for around £300 per month whilst 8 Mbps symmetric lines are around £1,400 per month.[87] In comparison, Verizon offer 15 Mbps (20 Mbps in some locations) symmetric business service over GPON for a cost of around £1000 per annum (though GPON may offer a lower level of service than dedicated products).[88]

Ideally one would consider the full range of price and quantity points allowing for quality of service, calibrate a demand curve and calculate the area under the demand curve. For a three-fold expansion in demand from 120,000 to 360,000 lines in the business market with GPON availability at around £1000 per annum, the increase in area under the demand curve (the gain in surplus) would be up to around £1-2 billion per annum, depending on the shape of the demand curve assumed (isoelastic or linear).

We note that this approach to estimation overlaps with the other estimates we have made for specific applications. The approach therefore needs to be refined to provide a more robust alternative estimate of value of next generation broadband to the business sector.

5.5.3 Doing new things

At the time of the dotcom crash in 2000 the hype about the internet appeared to vanish – with the benefit of hindsight one can see that perhaps a lot of the hype was right given the way the internet has embedded itself into our lives and business.

Not only the extent of what has happened in eight years, but in particular the details, were almost certainly not foreseen. Envisaging what people might do with next generation broadband and what business models might develop around it is therefore a challenge. However, some applications exist now that one can envisage growing rapidly, particularly as next generation broadband develops globally. In particular:

- "Vertical convergence" between content producers and consumers, and "disintermediation" of existing value chains.
- Two way video including video calling, video sharing, video monitoring, consumer telepresence and telemedicine.
- Network computing and software.
- Spectrum efficiency enabling high speed wireless applications.
- Government services.

We note that since each of these involves a transformation of existing value chains they are likely to take time to develop, even in the presence of next generation broadband. The benefit estimates we provide are "steady state" estimates and so would not be realised immediately.

The first two categories relate primarily to video, and Cisco, in their report "The Exabyte Era", have set out a road map of different video eras in terms of their impact on global traffic (Figure 5-2).[89]

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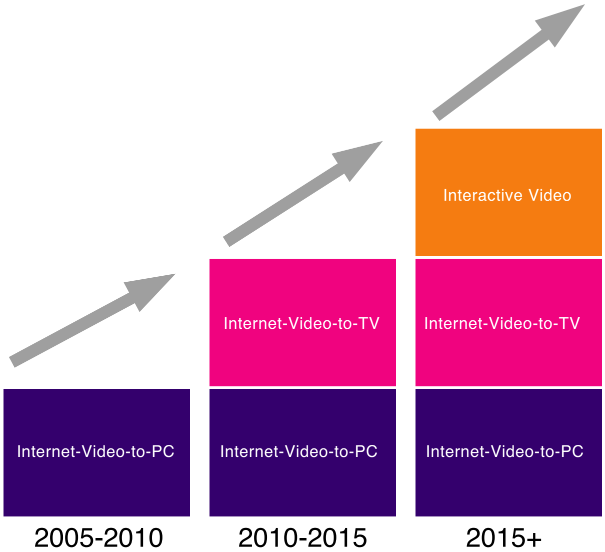
[87] See, for example, http://www.hostingsystems.co.uk/SDSL.asp

[88] http://www22.verizon.com/content/businessfios/packagesandprices/packagesandprices.htm

[89] Cisco. 14 January 2008. "The Exabyte Era." An exabyte is a billion Gigabytes. http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/net_implementation_white_paper0900aecd806a81a7.pdf

Figure 5-1



Source: Cisco, 2008

In the first wave video traffic delivered to the PC dominates – YouTube is a prime example. The benefits in terms of next generation access for this wave were captured under time savings and doing more of existing things.

The next two waves, internet video to the TV and interactive or two way video amount to new things – at least as mass market phenomenon and in terms of the "disruption" they will bring. Their impact is likely to be felt before they become major drivers of traffic, for example, video calling already generates significant traffic today: video traffic over MSN Messenger, for example, is roughly equal to all internet traffic in 1997.

5.5.3.1 Vertical convergence

By "vertical convergence" we mean content and software distribution models over next generation broadband that bring content production closer to consumption. These developments are beginning over broadband (but would be greatly enhanced by widespread availability of next generation broadband). As Thomas Lesinski of Paramount Pictures noted:[90]

> "In 2008 we will move full speed ahead online. It's the great hope for new revenue for the movie business."

Broadband is not the only enabler, and both the development of digital rights management (DRM) and devices/software that simplify the user experience are enabling an expansion in online distribution. However, the end user experience in relation to SD video content and HD in particular, may be far from perfect over broadband, particularly in households where people are trying to use simultaneously the internet and download content or large software applications.

Next generation broadband would transform the potential for vertical convergence, and fundamentally change the video on demand, TV, DVD and bricks and mortar video rental markets. Content

[90] Reported in The Economist. 21 February 2008. "Hollywood and the Internet – coming soon." http://www.economist.com/world/na/displaystory.cfm?story_id=10723360

providers would be less dependent on encryption systems and closed platforms, provided DRM is adequate and acceptable to consumers. New relationships could be expected to emerge. The beginning of this change is signalled by recent developments including:

- The Project Kangaroo initiative by the BBC, ITV and Channel 4 announced in June 2007 to provide a video on demand platform.
- The launch of BBC iPlayer catch up service in December 2007, and extension to Nintendo Wii and Virgin Media TV platforms in April and May 2008.
- An announcement by Paramount in December 2007 that they will put film on the web for free ahead of DVD launch supported by advertising.
- The launch of 'smart' TVs at the Consumer Electronics show in Las Vegas in January 2008. 'Smart' TVs have built in internet connection capability, tie ups with video services such as YouTube and wireless video streaming.
- Apple TV 'Take Two' announced in January 2008. The service allows rental of video including HD over the internet with a 24 hour viewing window anytime in the 30 days after download for $2.99 for library titles and $3.99 for new releases. The service is supported by a number of major content producers. The device also provides access to services such as YouTube and Flickr.
- The announcement by Warner Bros in April 2008 that they will release DVD and video on demand versions at or near the same time in the UK, and that DVDs will be released with a digital copy for download.[91]

Vertical convergence and the availability of large video catalogues online and on-demand would deliver the following kinds of benefits:

- Lower distribution costs via the elimination of physical media, storage/stock holding and distribution costs (and potentially time savings for consumers).
- The incremental value of on-demand versus planned or delayed consumption.
- Greater choice via the availability of back catalogues in particular.

The Netflix video rental service in the US can be compared with nascent online offerings to get some idea of relative costs. The charge for one DVD at a time is $4.99 including postage. This compares to $3.99 for new releases for the Apple TV services. This gives a price difference of $1 which we assume reflects a cost difference of 20 per cent. The Economist (February 2008) also reported that "*the studios get $18 per film from a Wal-Mart or a Best Buy and about $16 for a digital sale, but because of the lower costs they make about $3 more on each film when sold electronically.*" This implies a larger overall saving of $5, or 28 per cent.

To get an idea of the total market Screen Digest estimate that download will represent 3 per cent of the video market by 2011 and will be worth $570 million per annum in Western Europe – out of a total market of $19 billion.[92] The UK has a DVD retail market of around £1.3 billion per annum and a DVD rental market of around £300 million per annum.[93] Taking the combined market and assuming a

[91] FT. 3 April 2008. "Warner Bros brings window model to UK." http://www.ft.com/cms/s/0/ff5776d2-0116-11dd-a0c5-000077b07658.html?nclick_check=1

[92] Screen Digest. 4 September 2007. http://www.screendigest.com/reports/07onlinemoviestrat/FHAN-76PKY4/pressRelease.pdf

[93] Ben Keen. 2008. "The film market: trends and observations." Screen Digest.

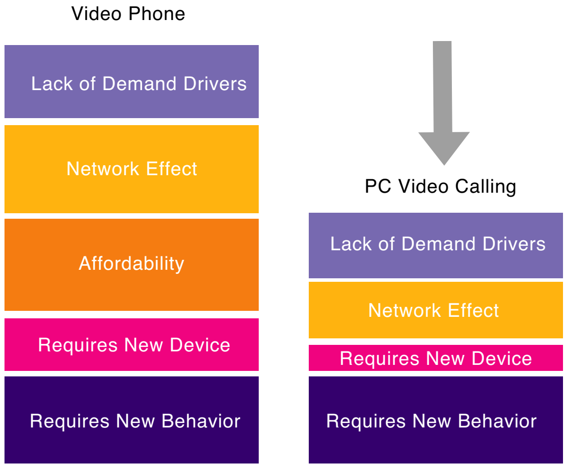
saving of 25 per cent would give a gain of £400 million per annum – though the download market share would take time to build up with the rollout of next generation broadband itself taking time. For 80 per cent network coverage the value is £320 million per annum.

Whilst we do not know the potential value of additional choice in the video market estimates suggest it has been substantial in relation to the online book market. On line bookstores offer consumers lower prices (around 9-16 per cent differences have been found); greater product variety; and search tools that make it easier to find a book than in a brick and mortar store. One study found that increased product variety of online bookstores enhanced consumer welfare by $731- $1,030 million, between 7 and 10 times as large as the gains from lower prices.[94]

5.5.3.2 Internet video communication and collaboration

Video communication has suffered numerous false dawns with the failure of videophone services, but high quality services in the corporate market and development of consumer services based around the PC could drive take-off of video communication. Figure 5-3 shows how the barriers to video communication are falling.

Figure 5-3



Source: Cisco, 2008

Leveraging off an installed base of PCs, free Instant Messaging (IM) and VoIP communication platforms, improved webcams have created the potential for network effects to kick in fostering rapid future growth in video communication and collaboration. Further, the potential market has broadened considerably with the advent of a new generation that has large networks of virtual friends.

In the consumer market an illustrative service is Skype Video which offers a "High Quality Video" service with specific high end webcams (though relatively inexpensive) and computers with dual core processors over a recommended connection speed of 384kbps.[95]

Over the long term, the consumer market for video calling can be expected to develop, and over time demand could grow for higher definition services on larger screens. Only next generation broadband

[94] Brynjolfsson, Hu and Smith. November 2003. "Consumer surplus value in the digital economy: estimating the value of increased product variety at online booksellers." *Management Science*. Volume 49. Number 11.

[95] http://www.skype.com/allfeatures/videocall/#high-quality-video

would be able to support truly HD video calling over a large panel display (which might be an HD screen in the living room rather than a PC in future).

The consumer market and corporate market might also be expected to reinforce one another with personal use of video calling creating demand for such services in the work environment, and experience of high definition life size image systems in the corporate environment creating demand for improved services at home.

In the corporate market an illustrative service is the Cisco "TelePresence" service launched in 2006. Services have also been developed by HP (Halo – which was developed for Dreamworks whilst they were collaborating with Aardman Animations on a Wallace and Gromit film)[96] Tandberg,[97] Polycom[98] and others including resellers of services such as Wire One (acquired by BT on 10 April 2008).[99]

The Cisco service is available in two formats. The 1000 system requires symmetric bandwidth of 3-4 Mbps whilst the 3000 system requires symmetric bandwidth of 9-12 Mbps (these bandwidth requirements are likely to be at the low error rates that only fibre can provide).[100] Cisco reportedly plans to bring a Telepresence system to homes within three years.

Video conferencing offered over next generation broadband could have an impact on business travel. A study for Telstra in Australia considered the potential environmental benefits of telecommunications including high definition video conferencing.[101] The authors assumed that live high definition links might save one third of business travel. Based on 228 million passenger movements per annum in the UK, and assuming 12 per cent are business passengers, gives 27 million business flights per annum.[102] Assuming 10 per cent of these can be avoided with high definition video conferencing, that each flight involves foregoing 3 hours of productive time (including travel to and from airports etc) at an average value of £29 per hour, and that the costs of video conferencing and air travel plus accommodation are equal, the saving would be £235 million per annum. For 80 per cent network coverage the value is £190 million per annum.

We also note that the possibility of substituting video communication for air travel in the business market is not discussed in the official Department for Transport forecasts.[103] This is an area where the possible future relationship between communications and transport might be considered in more depth.

Video will also have applications in the health care sector – in particular to support training and collaboration amongst health care professionals, and to improve remote diagnostics and patient monitoring. These applications are discussed in Box 5.2 (section 5.5.3.5), and a specific illustrative example of the potential wider social benefit in relation to pandemic management is discussed in Box 5.3 (section 5.7.5).

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[96] http://h71028.www7.hp.com/enterprise/cache/570006-0-0-0-121.html

[97] http://www.tandberg.com/

[98] http://www.polycom.com/emea/en/products/video/video.html

[99] http://www.wireone.com/html/companyInfo/press/2008_04_10.html

[100] http://www.cisco.com/en/US/products/ps7060/index.html

[101] Climate Risk. 2007. "Towards a high-bandwidth low-carbon future." http://www.climaterisk.com.au/wp-content/uploads/2007/CR_Telstra_ClimateReport.pdf

[102] CAA. January 2008. "Trends in UK air passenger traffic." http://www.caa.co.uk/application.aspx?catid=14&pagetype=65&appid=7&newstype=n&mode=detail&nid=1549

[103] Department for Transport. November 2007. "UK air passenger demand and CO2 forecasts." http://www.dft.gov.uk/pgr/aviation/environmentalissues/ukairdemandandco2forecasts/airpassdemandfullreport.pdf

5.5.3.3 Network computing and software

Various developments in terms of software and work practices (mobility and nomadicity) point to the possibility that much of what is currently provided as IT within the firm will in future be purchased as a service. Another way of thinking about this transformation is that the distinction between local and wide area networks will blur.

Software developments include the development of Web 2.0 software including various software applications over the internet such as Google apps, Zimbra collaboration suite and Microsoft Office Live and Live Mesh. Other developments include software that enables web applications to work offline such as Google Gears and Adobe Air. Centralised computing is following centralised storage in achieving efficiency gains, with virtualisation technologies allowing large numbers of servers to be used as a virtual machine in combination to meet demand.[104] This not only lowers the cost of computing, but also reduces energy requirements and greenhouse gas emissions. Examples include Amazon Elastic Computing Cloud (EC2) and Amazon Simple Storage Service (Amazon S3).

Combined with broadband and next generation broadband in particular, these developments can be expected to revolutionise IT – in an analogous manner to what the development of reliable centrally supplied electricity did for manufacturing and service industries a century ago.[105] Next generation broadband will facilitate this transition by removing upload and download speeds as a constraint on using a centralised server and by improving reliability to the point where enterprises are prepared to rely on the centralised supply of IT services.

Progressive developments can be envisaged, with email/calendar functions and back-up moving online, followed by file storage. Once this phase is achieved many SMEs could dispense with a local server. The move from local office software applications to central service provision might take longer. Many home users have already moved to email and calendar applications provided online, and some use online back-up given the convenience and added security of offsite backup (though upload speeds of 0.7 kbps are a practical constraint).

The number of enterprises by size in the UK is shown in **Table 5-4:**[106]

Table 5-4: Enterprises by size

	Enterprises	Employment (000)	Turnover (£ million)
All	4,550,930	29,331	2,820,025
With employees	1,280,830	25,761	2,612,408
Small (0-49 employees)	1,242,865	7,418	784,800
Medium (50-249 employees)	29,855	2,991	401,559
Large (250 or more employees)	8,115	15,352	1,426,048

[104] The Economist. 17 January 2008. "Virtualisation." http://www.economist.com/business/displaystory.cfm?story_id=10534566

[105] Jovanovic and Rousseau. January 2003. "General purpose technologies." http://www.econ.nyu.edu/user/jovanovi/GPT.pdf

See also Nicholas Carr. January 2008. "The big switch." W.W. Norton.

[106] BERR. SME statistics. http://stats.berr.gov.uk/ed/sme/

SMEs account for the vast majority of enterprises with 1.27 million enterprises (99 per cent of the total and 40 per cent of total employment). Restricting attention to enterprises with up to 49 employees there are still 1.24 million.

Assuming savings of £350 per annum per person in avoided IT support costs by moving to central server provision, email, calendar and back-up (with office applications remaining local and IT costs other than server costs constant);[107] the total saving – if 30 per cent of small enterprise staff use IT – would be around £620 million per annum. For 80 per cent network coverage the value is £500 million per annum. Centralised servers and applications may also offer better quality of service.

Whilst some benefits will arise from the development of software utilising existing broadband, a large scale transition to computing and software as a service for SMEs is only likely to come about when broadband is fast and dependable i.e. when next generation access is available. There may also be benefits in terms of mobility, lowered entry barriers and ease in scaling up the enterprise.

5.5.3.4 Spectrum efficiency

Next generation broadband access infrastructure would be complementary to the development of short range high speed wireless networks ('short tail' wireless networks) providing high-speed broadband access to a high density of users.[108] As William Webb noted:[109]

> *"Fibre optic cable remains potentially transformational for the whole telecommunications industry. The extent to which fibre cables are brought within 100-300 metres of peoples' homes will determine the viability of a massive upgrade of wider area mobile radio data speeds."*

This would give consumers nomadic access while not sacrificing the speed and reliability of fibre. Pico cells within premises would allow more efficient use of spectrum, and potentially the utilisation of higher frequency licence exempt spectrum at 40 GHz and above.

The opportunity cost of spectrum used by today's wireless networks is high, and a 'short tail' network would allow improved performance at a much lower opportunity cost. If spectrum for mobile applications remains scarce in a next generation broadband environment, then one can think of the value of UHF spectrum released if TV is moved from terrestrial broadcast to delivery over next generation broadband as indicative of the potential gains (considered in the Section 5.6.1).

Alternatively, if one considers that next generation broadband will eliminate or substantially reduce spectrum scarcity for mobile wireless applications, then the gain is the reduction in spectrum input costs for the mobile sector from a move to a short tail network. Either calculation could yield a substantial benefit estimate – though we note that our estimates of opportunity cost are based on the value of spectrum today, however, the value of spectrum in future may differ and the value is therefore uncertain.

[107] Assuming annualised server costs foregone of £100 per person per annum and savings on IT support of 50 per cent on an assumed cost of £600 per person per annum (£50 per person per month).

[108] Cochrane. 2006. "The future of regulation – not." In Ofcom, "Communications – the next decade."

[109] Webb. 2007. "Wireless Communications: The Future." John Wiley. Page 209.

5.5.3.5 Government services including education and health

Private benefits could also be realised in relation to government services, for example, health and education (there are also wider social benefits). Illustrative examples of benefits in relation to government services are provided in **Box 5-2**.

Box 5-2: Illustrative examples of benefits in relation to government services

The OECD (May 2008) refer to a number of public sector initiatives and the scope for savings in future, particularly in relation to the application of advanced broadband in the social sectors including health, care of the aged and disabled and education.[110] The OECD draw on studies, particularly those by Robert Litan. However, these do not attribute benefits to different forms of broadband including wireless, current and next generation broadband. Our focus is on the narrower question of the potential incremental benefits of next generation broadband which the following examples seek to illustrate.

An illustration of the constraint where bandwidth is shared is provided by schools where it may be desirable for a whole classroom of 30 children to view video simultaneously. At present this might be achieved using a single PC and projection system. However, to enable individual class members to experience a satisfactory interaction with visual material online a high connection speed for the classroom or school as a whole is required. High bandwidth not only enables individual interaction, but also reduces the likelihood of download delays leading to classroom disruption. An illustration of the difference a high speed connection can make is provided by experience in Scotland where high speed connections have been provided to a number of schools using point-to-point fibre.[111]

In the health sector, improved connectivity could lower service delivery costs and improve service via e-health and telemedicine. In view of the potential public benefit and the potential for efficiency gains in service provision the European Union currently sponsors more than 50 e-health projects under the 6th Framework Programme. We note that a number of future applications in relation to patient monitoring may involve relatively modest rates of data transfer, and may be best suited to wireless connectivity.[112] Other applications may require very high bandwidth and reliability/quality of service – potentially beyond the capability of wide area fibre networks and best suited to dedicated point to point deployments. However, a range of current and potential applications would benefit from wider availability of next generation broadband including virtual face-to-face consultations for patients and caregivers.[113]

Next generation broadband would also facilitate social inclusion and care for the elderly, and may also facilitate physical social distancing and improved management of pandemics – a potential benefit we consider under wider social benefits.

[110] OECD. May 2008 (Pre-publication version). "Broadband growth and policies in OECD countries." http://www.oecd.org/dataoecd/32/57/40629067.pdf

[111] BBC. 5 December 2007. "Broadband digital divide looms." http://news.bbc.co.uk/1/hi/technology/7115850.stm

[112] "Health technology scenarios and implications for spectrum." A report by Fathom Partners. Forthcoming – summarised in Ofcom. May 2008. "Tomorrow's wireless world." Page 9. http://www.ofcom.org.uk/research/technology/overview/randd0708/randd0708.pdf

[113] Scottish Centre for Telehealth. January 2008. "HealthPresence Trial." http://www.sct.scot.nhs.uk/HealthPresence.html

5.6 Wider economic costs and benefits

5.6.1 Non-appropriable value

Two areas of potentially non-appropriable private value (to the investor) are land and buildings subject to sale and leaseback arrangements and UHF spectrum that is non-tradable and currently utilised for broadcasting. In both of these areas next generation broadband may allow the release of value, but existing contractual and institutional-policy arrangements may limit the potential realisation of value by investors, and therefore potentially the realisation of value for the economy.

In relation to land and buildings, we have not estimated the value associated with a move from telephone exchanges to alternative uses. However, the fact that KPN in the Netherlands originally anticipated that they could fund almost the entire costs of an FTTC deployment via the sale of land and buildings suggests the value may be large. Because BT has already entered into sale and lease back arrangements this value may only be partially captured by BT if they invest in next generation broadband.

Gains in spectrum efficiency could flow either from the substitution of local within building transmitters and next generation broadband connections for higher cost spectrum and base stations (a private benefit as discussed in Section 5.5.3.4); and/or the substitution of fibre carriage for terrestrial broadcasting with an accompanying release of UHF spectrum (a wider economic benefit given that UHF spectrum is non-tradable). We note that such a transition would have to overcome a number of hurdles and would take time, though some spectrum might in principle be freed up on a regional basis as next generation broadband investment proceeded.

The value of gains in spectrum efficiency can be estimated approximately by considering the value of UHF spectrum which is around £5 billion or an annualised value of £500 million per annum (see Appendix B). Such gains would only be realisable in the medium to long term, by which time the value could have changed materially. The estimates should therefore be interpreted with caution, and kept under review.

5.6.2 Externalities

As explained in Section 3.3.2, externalities arise when economic activity generates costs or benefits for third parties that are not mediated by the market. Externalities include costs in terms of disruption and traffic congestion caused by network construction, potential benefits related to reduced traffic congestion enabled by video communication, and the impact of the transition to next generation broadband on greenhouse gas emissions.

5.6.2.1 Traffic congestion

External costs in terms of congestion and other disamenity would be most significant where existing ducts or overhead poles cannot be utilised and road works are required. Overall there are roughly one million road works in total in the UK per annum, lasting on average five days and costing perhaps

£600 per roadwork per day.[114] We have not attempted to estimate the overall costs of externalities related to road works for next generation broadband investment given a lack of information on the extent and duration of road works required.

There is evidence from the US that existing developments in terms of ICT, broadband and mobile communications are changing road traffic patterns and that growth in peak time congestion has stopped.[115] Next generation broadband would also facilitate improved remote IT services and video communication, both of which could contribute to reduced travel by reducing the need for meetings and facilitating home working. In the absence of efficient congestion charging such costs are externalities. Were efficient congestion charging introduced then any such gains would be reflected in private benefits.

5.6.2.2 Greenhouse gas emissions

In relation to greenhouse gas emissions, the picture is complex given the pervasiveness of emissions throughout the economy and the wide range of potential impacts of next generation broadband on the economy.[116] A simple calculation of the "carbon footprint" of a next generation broadband network versus a copper network is only a partial measure of overall impact – and will not necessarily indicate the overall direction of impact. In qualitative terms the effects are:

- Construction of a fibre network would increase emissions.
- A passive optical network (FTTH) would consume less power than a copper network, though optical network termination equipment powered from the customer premises may raise overall power consumption to comparable or higher levels.[117]
- Movement of computing from distributed servers and PCs to central servers with virtualisation software would allow much more efficient computing and so save power.
- Data traffic associated with higher bandwidth, in particular video, could greatly increase power consumption (over the past 5 years server power consumption has grown roughly 15 per cent per annum in Europe and is now around 2 per cent of overall electricity consumption).[118]

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[114] Goodwin. 2005. "Utilities street works and the costs of delays." http://www.transport.uwe.ac.uk/research/projects/njugcongestionreportfinal4goodwin.pdf

[115] Economist. 10 April 2008. "The new oasis – nomadism changes buildings, cities and traffic." http://www.economist.com/specialreports/displaystory.cfm?story_id=10950463

[116] The Intellect February 2008 report "Energy and the Environment" provides an indication of the range of impacts and potential impacts of ICT on emissions. http://www.intellectuk.org/content/view/806/28/

[117] BT networks consumed 1992 GWh in 2007, or around 9W per customer assuming 25 million customers. http://www.btplc.com/Societyandenvironment/SocialandEnvironmentReport/section.aspx?sectionid=a6314501-0d2f-4a36-86a9-42e4e12be6c4

A GPON network is estimated to use 11kW for 10,000 users, or 1.1W per user. See page 15: http://www.openreach.co.uk/orpg/products/nga/downloads/Fibre_Products_Industry_Workshop_Slides_4th_Oct_2007.ppt

However, power for the Huawei ONT would be obtained from the customer premise, and the proposed unit for Ebbsfleet operates with a power consumption of around 10W (though other retail equipment may add to this). See page 47: http://www.openreach.co.uk/orpg/products/newproducts/fttp/downloads/FTTP%20HLSD%20v1.1%204th%20Mar%2008.pdf

Further, other equipment powered from the customer premise would be required. Whilst power requirements of non-Openreach equipment are unknown, Openreach have assumed the Huawei ONT plus 50W per premise as a working assumption in cabinet design. See page 24: http://www.openreach.co.uk/orpg/products/nga/downloads/technical%2010th%20april%20slide%20deck.pdf

- There are complex and ambiguous behavioural effects, for example, telepresence could substitute for travel whilst virtual tours and interactions could stimulate travel.
- If next generation broadband is a good investment it will result in income growth and the positive impact of this on emissions via consumption such as travel could dominate other effects. A Swedish study of the impact of energy efficiency measures on emissions illustrates how indirect effects can dominate.[119]

However, to the extent that the above effects are already reflected in market prices they are not relevant "external" costs in terms of cost benefit analysis. To some extent they clearly are internalised with high levels of fuel excise duty, European Emissions Trading Scheme (ETS) and other interventions in place.

Some policy approaches may also limit the scope for ICT and next generation broadband to contribute to emissions reduction. For example, intermediate targets for renewables and biofuels rather than greenhouse gas abatement *per se* are likely to limit the scope for next generation broadband to contribute to emissions abatement.[120] Whilst a carbon charge would promote demand side substitution of communication over next generation broadband for transport, a renewable target that delivered greenhouse gas reduction goals would leave limited scope for next generation broadband to contribute. Indirect approaches to greenhouse gas abatement can also be expected to involve far higher costs per tonne of carbon abatement than an efficient carbon price.[121]

In conclusion, the net impact of next generation broadband on greenhouse gas emissions is unclear. However, it is clear that next generation broadband provides important opportunities for substitution away from carbon intensive activities, provided other policies – in particular a carbon price – provide an incentive to do so.

5.6.3 Piracy

As the DCMS paper "Creative Britain – New Talents for the New Economy" noted:[122]

> *"Online IP infringement, in particular, continues to grow. If creative artists cannot earn a living as a result of their work, then our creative industries will not thrive."*

Illegal content sharing has had a significant impact on the creative industries as a whole. For example, IFPI figures show growth in legal digital sales of music tripled in 2005 to $1.1 billion, almost doubled in 2006 to about $2.1 billion, and rose 38 per cent to $2.9 billion in 2007 (now 15 per cent of total revenue). In line with changing consumption habits, physical sales, which include CDs, tapes

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[118] Koomey. December 2007. "Estimating regional power consumption by servers: a technical note." http://www.amd.com/us-en/assets/content_type/DownloadableAssets/Koomey_Study-v7.pdf

[119] The study found that mandated energy efficiency standards (as opposed to inducing it via a price change, say via a carbon tax) could increase greenhouse gas emissions by lowering the cost of energy consumption and raising income available for other consumption. Runar Brannlund, Tarek Ghalwash and Jonas Nordstrom. January 2007. "Increased energy efficiency and the rebound effect: Effects on consumption and emissions". *Energy Economics*, Volume 29 Issue 1.

[120] See for example: FT. January 2008. "EU scientists query bloc's biofuel strategy." http://www.ft.com/cms/s/0/f09ceb44-c544-11dc-811a-0000779fd2ac.html

[121] Defra. December 2007. "The social cost of carbon and the shadow price of carbon: what they are, and how to use them in economic appraisal in the UK." http://www.defra.gov.uk/environment/climatechange/research/carboncost/pdf/background.pdf

[122] DCMS. 22 February 2008. "Creative Britain – New Talents for the New Economy." http://www.culture.gov.uk/NR/rdonlyres/096CB847-5E32-4435-9C52-C4D293CDECFD/0/CEPFeb2008.pdf

and vinyl, fell from $21.1 billion in 2004 to $19.6 billion in 2005, $17.5 billion in 2006 and by 16.7 per cent to an estimated $15 billion in 2007.[123] Legal online sales are growing but are not yet compensating for the decline in physical sales.

However, the incremental impact of next generation broadband on piracy is unclear. In a worst case scenario it could lead to increased sharing of much larger files, including more video and perhaps even whole music catalogues. In a best case scenario it could lead to the development of technical and commercial innovations to counter illegal file sharing and drive business to new legitimate services that meet demand for online content. [124] Currently there is no consensus about which of these is the most likely scenario. The net incremental impact of next generation broadband on piracy is therefore unclear.

5.6.4 Network Effects

In relation to next generation broadband, network effects will apply to some extent, particularly for two-way applications such as high definition video conferencing. However, applications developers may partially overcome such constraints by offering different levels of service depending on the quality of an end-to-end connection. For example, Skype video calling operates in 'HD' mode offered if web cam quality, connection speed and computing power meet certain requirements.

Network effects may also apply to some of the online services that will prove complementary to next generation broadband. However, many services developed for broadband would simply be much better with next generation broadband. In other words the applications already exist. Further, they are typically global and are not therefore dependent on next generation broadband rollout in the UK. In the longer term there may be benefits in terms of public service provision and transformation from universal availability of next generation broadband – though network effects during the transition may be modest.

Overall, we take a conservative view and consider that UK specific network effects in relation to next generation broadband may be modest, but are necessarily positive. To the extent that high levels of coverage are required for the transformation of some government services in particular, network effects would be greater (these benefits would not necessarily build up progressively in line with "Metcalfe's law" – but would arise once some threshold of coverage and usage had been achieved).

5.6.5 Spill-over and virtual agglomeration

ICT and broadband improve information flows and open up new ways of organising economic activity and of collaborating – they might therefore be expected to enhance knowledge spill-overs (which may be non-local).

There is also evidence of positive externalities in terms of productivity from agglomeration i.e. spatially concentrated economic activity, particularly in cities.[125] This has become a focus of attention in

[123] IFPI. January 2008. "Digital Music Report 2008." http://www.ifpi.org/content/library/DMR2008.pdf

[124] Reported in The Economist. 21 February 2008. "Hollywood and the Internet – coming soon." http://www.economist.com/world/na/displaystory.cfm?story_id=10723360

[125] Venables. 2004. "Evaluating urban transport improvements: cost-benefit analysis in the presence of agglomeration and income taxation." http://www.econ.ox.ac.uk/members/tony.venables/Xrail7.pdf

relation to transport infrastructure and transport project appraisal (including London Crossrail) with the benefits of agglomeration identified by the 2006 Eddington Transport Study:[126]

> *"Transport improvements can expand labour market catchments, improving job matching, and facilitate business to business interactions. Transport's contribution to such effects is most significant within large, high-productivity urban areas of the UK. London is the most significant example, adding 30 per cent to the time saving benefits of some transport schemes."*

A subsequent review of transport appraisal notes that:[127]

> *"…reducing transport costs can bring firms and workers closer together, generating benefits from better functioning markets. Empirical evidence has shown that in an area with a mass of firms and workers, i.e. an agglomeration, there is often a productivity premium. This premium may result from increased access to product and input markets and the sharing of knowledge and expertise."*

It is useful to consider ways in which next generation broadband might complement and/or substitute for transport. In particular:

- The extent to which next generation broadband would allow some of the gains from agglomeration to be captured without agglomeration.
- The extent to which next generation broadband might reduce the congestion costs associated with agglomeration.

A further potential interaction between transport and communications is that improved communications may encourage greater physical clustering of some activities.[128] The reason for this is that it is feasible with improved communications to sell services to the wider market, but it is nevertheless advantageous for groups of workers to locate together to facilitate face-to-face interaction (for which communications, and certainly existing communications technology, is only a partial substitute) and to allow labour market pooling whereby both firms and employees benefit from the enlarged pool of similar jobs and skills. As Glaeser and Ponzetto (2008) note:[129]

> *"Urban proximity can reduce the costs of shipping goods and speed the flow of ideas. Improvements in communication technology might erode these advantages and allow people and firms to decentralize. However, improvements in transportation and communication technology can also increase the returns to new ideas, by allowing those ideas to be used throughout the world."*

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[126] The Eddington Transport Study. December 2006. "The case for action: Sir Rod Eddington's advice to Government." Figure 2. http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/

See also Eddington and Department for Transport. December 2006. "Agglomeration in the UK and role of transport policy." Research Annexes: Volume 1. Paragraphs 14 and 15.
http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/researchannexes/researchannexesvolume1/

[127] Department for Transport. October 2007. The NATA refresh.
http://www.dft.gov.uk/consultations/open/consulnatarefresh/pdfnatarefresh.pdf

[128] Krugman. 2001. "Increasing returns and economic geography." *Journal of Political Economy*. Volume 99. Issue 3.
http://math.stanford.edu/~lekheng/krugman/geography2.pdf

[129] Glaeser and Ponzetto. January 2008. "Did the death of distance hurt Detroit and help New York?" Harvard Institute of Economic Research.
http://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID1080284_code223968.pdf?abstractid=1080284&mirid=1

In conclusion, the service capabilities of next generation broadband would allow some of the productivity benefits associated with urban agglomeration to be realised without agglomeration, and would also help ameliorate the congestion costs associated with agglomeration. We have not attempted to quantity these potential benefits, but consider that they could be large. We therefore suggest that they might be addressed in follow up work to The Eddington Transport Study by the Department for Transport.

5.6.6 Competition in the economy

5.6.6.1 Competition in the telecoms market

Given the prospects for upgraded cable broadband service, and developments in wireless technology, next generation broadband will face some competition. However, next generation broadband is likely to see limited scope for competition in many areas, and little prospect of deployment of new competing fibre networks in the same location. Further, next generation broadband may offer less scope for the commercially viable unbundling of network elements.

The manner in which the transition to next generation broadband is managed and the set of regulated access products in a next generation broadband environment are therefore key to preserving competition in the telecoms market where considerable benefits have been achieved.[130]

Consistent with the overall regulatory model developed in the UK we assume that where next generation broadband infrastructure is an infrastructure bottleneck, that access to fit for purpose access products will be provided on an equivalence of inputs basis (EOI) to support competitive service provision. We note that a bit-stream Ethernet product available on an EOI basis is under development in relation to the FTTH deployment at Ebbsfleet.[131]

5.6.6.2 Competition in the wider economy

Looking beyond the network itself, next generation broadband with active electronics and wholesale access should lower end user switching costs and entry barriers for service providers, including internet based services. Next generation broadband would contribute to lower entry costs for small businesses and new business models in the wider economy, including the development of software as a service and a transformation of the IT industry. Elements of the economy would also be further opened to international competition by next generation broadband. As was noted in March 2008 by HM-Treasury:[132]

> *"...increased speed of communication has expanded the range of services which it is feasible to trade, leading to a more integrated global market. Firms are able to specialise, take advantage of economies of scale, and penetrate global markets. The production and consumption of information-intensive services activities, such as research and development (R&D), inventory management, quality control, professional and technical services, and banking and insurance can*

[130] Heaney and Williamson. January 2004. "Reaping the telecoms dividend." http://www.cw.com/docs/newsletters/agenda/ReapingtheTelecomsDividend.pdf

[131] Chinyelu Onwurah, Ofcom. 15 May 2008. "Next generation build." Openreach. "Future access forum." Pages 16-22. http://www.openreach.co.uk/orpg/products/nga/downloads/Main_slide_deck_final.pdf

[132] HM-Treasury. March 2008. "The UK economy: analysis of long-term performance and strategic challenges." Page 63. http://www.hm-treasury.gov.uk/media/6/2/bud08_strategicchallenges_645.pdf

be separated and traded across borders. Future developments in ICT are likely to take this process further."

Overall, we consider that next generation broadband would be positive for competition in the economy since it would facilitate greater trade in services (by opening up new markets dependent on fast reliable bandwidth such as online IT, international collaboration and "unbundling" of supply chains) and improved labour market search and matching (via two way video). Whilst this would bring associated benefits in terms of innovation and/or lower prices to consumers, we do not attempt to quantify these benefits in our cost benefit analysis.

5.6.7 Resilience, adaptability and policy options

Next generation broadband could further increase resilience, particularly given the improvement in connectivity that would be available to SMEs. Not all of this increase would be reflected in individual private willingness to pay, given network effects. Further, next generation broadband would increase resilience to supply side shocks such as an oil price shock (as currently experienced), industrial action, terrorism and potential natural disasters such as an influenza pandemic.

Next generation broadband would increase resilience to such events by enabling greater scope for substitution away from dependence on oil if the price rises, and greater scope to substitute for travel in the event of industrial action, terrorism and pandemics. Further, the option to avoid travel by working from home, utilising shopping online and telepresence could limit the spread of a pandemic at an early stage (an issue we discuss further in Section 5.7.5 in relation to wider social costs and benefits).

In addition to the direct economic benefits of greater resilience we note that reduced economic volatility and susceptibility to shocks would be likely to contribute to wider social benefits including greater social cohesion.

In a changing world options are valuable, both to investors and policy makers. Next generation broadband might make some policy options more feasible by lowering adjustment costs. For example, the trade-off between output and carbon abatement might be smaller in an economy with an extensive next generation broadband network.

5.6.8 Excess burden of taxation

These considerations only apply if the government contributes resources towards next generation broadband investment. If public funds rather than voluntary user payments are used to fund next generation broadband, then an additional cost is incurred in terms of the economic cost of raising taxes – the so called deadweight loss or excess burden which refers to the economic welfare cost due to reduced incentives to participate in the labour force and to save and invest arising from taxation.

We make no assumptions for the use of public funds in our scenarios. However, we note that one estimate of the excess burden is that it is in the range 25-50 per cent of taxation.[133] Other estimates

[133] Edgar. March 1997. "On the marginal welfare cost of taxation." *American Economic Review*. Volume 77. Issue 1.

are reviewed in Boardman *et al* (2006) giving a range 33-46 per cent averaged across all taxes.[134] Public investment in next generation broadband would therefore need to generate overall returns that exceed both the public financing cost and the excess tax burden to be worthwhile in economic welfare terms.

Another way of measuring the opportunity cost of public funding is to consider what must be foregone in terms of other investment if public support is forthcoming for next generation broadband (assuming overall public funding and taxation is fixed).

5.7 Wider social costs and benefits

We consider the following categories of wider social cost and benefit: educated citizens; informed democracy, cultural understanding and social inclusion; home working and its impact on community and education; inclusion and disability; and social capital, resilience and trust.

We also note that a number of costs and benefits that might be categorised as wider social have been considered under private (elements of government services) or wider economic (externalities for example). The discussion of costs and benefits in this section should therefore be considered alongside the other categories of costs and benefits discussed.

Finally, we acknowledge that making definitive statements about the wider social costs and benefits of future technologies is particularly difficult in the light of uncertainties about impacts. What we hope is that a more qualitative discussion can help inform future choices.

5.7.1 Educated citizens

The benefits of next generation broadband in relation to publicly funded education are captured under private benefits. Here we focus on other education, including lifelong learning, which may be socially desirable but is not purchased by the Government. Broadband has greatly expanded the range of knowledge and learning material accessible to citizens, and next generation broadband would further improve ease of access. For example, a study found that internet use had both a direct positive relationship to subjective health, as well as an indirect positive relationship, mediated through social support.[135]

However, the flow of information is now two way with citizens contributing their own experience and knowledge. This opens up new possibilities in relation to health care for example, with citizen generated information providing an increasingly valuable resource online.[136] If improved health information results in a healthier population, there may be benefits from this that go beyond private benefits.

[134] Boardman, Greenberg, Vining and Weimer. 2006. "Cost-benefit analysis – concepts and practice." Third Edition. Pearson Prentice Hall. Page 428-429.

[135] Wangberg et al. December 2007. "Relations between internet use, social-economic status, social support and subjective health." *Health promotion international*. http://heapro.oxfordjournals.org/cgi/content/full/dam039v1

[136] Economist. September 2007. "Health 2.0". http://www.economist.com/printedition/displaystory.cfm?story_id=9719054

5.7.2 Informed democracy, cultural understanding and social inclusion

This section focuses on the issue of democracy, cultural understanding and social inclusion. The evidence available is patchy and incomplete: the aim is to provide an indication of the key issues to be addressed and give some examples of relevant data.

Wider democratic participation, we can assume, should help ensure that decisions taken are better ones, and more legitimate. But participation in national elections has declined in most mature democracies in recent decades, as has membership of mass political parties and other forms of formal involvement in democratic life. Whilst it is acknowledged that new forms of participation –for example through pressure groups or phone-ins – remain at healthy levels, a significant body of opinion warns that there has been a decline of democratic participation and legitimacy.[137] In this context, E-voting, virtual deliberation, social networking and various forms of internet enabled direct public involvement in decision-making have been proposed as a means to encourage new forms of democracy by reducing the costs of participation.[138] At the same time, as early adopters exploit these new opportunities to have their voices heard, experts have raised questions about the democratic and citizenship implications of rising inequalities of access to new communications technologies.

So it is not the case that there will be a simple positive correlation whereby expansion of access to next generation broadband will lead to corresponding improvements in the democratic process in the UK. Offering new means to express preferences and voice concerns in the democratic process (for example through video) may offer benefits, but improving access only for a particular group may in fact undermine democracy by creating inequalities of access to crucial communications services.[139] Edward Lucas of the Economist in a feature on technology and government noted that:[140]

> *"I think ultimately technology intensifies whatever the style of government is. If you have a basically benign, honest, public-spirited government, in the end technology will make it more benign, more public-spirited, more honest."*

Broadband, and to a greater extent next generation broadband, facilitate the production of user generated content and access to a diversity of content via Web 2.0 technologies and the "long-tail" of content. In relation to informed democracy for example, there has been an explosion in the use of the internet in political campaigning and in citizen participation in political debate.[141] The British Election Survey 2005 shows that, for a sample restricted to those who express high levels of political interest there is no clear relationship between voter turnout and internet use, whilst for those with none or low levels of political interest higher levels of internet usage do seem to boost turnout.[142]

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[137] Benjamin Barber. 1984. "Strong democracy: participatory politics for a new age." Berkeley: University of California Press; Robert Puttnam. 2000. "Bowling Alone: The Collapse and Revival of American Community."

[138] Coleman, S. 2004. "Connecting Parliament to the Public via the Internet: Two Case Studies of Online Consultations." *Information, Communication and Society* Volume 7. Issue 1. Pages 1-22.

[139] Damian Tambini. 2006. "What Citizens Need to Know. Digital exclusion, information inequality and rights." In Ofcom. 2006. "Communications: the Next Decade". http://www.ofcom.org.uk/research/commsdecade/

[140] The Economist. 14 February 2008. "Technology and Government." http://www.economist.com/research/articlesBySubject/displaystory.cfm?subjectid=348963&story_id=10638222

[141] The Pew Research Centre. January 2008. "The Internet gains in politics." http://www.pewinternet.org/PPF/r/234/report_display.asp

[142] Reported in Anderson and Stoneman. 2007. "Predicting the socio-technical future (and other myths)." Chimera Working Paper Number 2007-10. http://www.essex.ac.uk/chimera/content/pubs/wps/CWP-2007-10-predicting-socio-tech.pdf

If we assume then that extending the quantity and quality of broadband access could be a contributing factor to enabling improved democratic participation, there remains the question of whether individual citizens themselves would be likely to procure the level of access necessary to benefit. The benefit of living in a healthy democracy appears to be an externality in the sense that it is not realised through private benefit. In political science the nature of motivation to participate has been the source of long term controversy, but there is a consensus that motivations are complex and mixed.[143]

It is important to note that if video conferencing and video calling does open up new forms of participation, or if next generation broadband more generally does enhance democratic participation (and for the reasons given it is by no means clear they will) it is important that this does not exclude some voices (e.g. rural dwellers) from debates.

MySociety (www.mysociety.org), the leading E-Democracy website offers a variety of web enabled e-democracy services, including: communications with MPs, realtime alerts on House of Commons interventions by MPs, assisted FOIA requests from public authorities, the recently launched 'tellthemwhatyouthink.org' that permits people to take part in government consultations, and various services that enable local community groups to reduce costs of participation. All current services are text-based and designed to run at low connection speeds.

An over-arching problem with such services are that they are text based: they tend to be dominated by people that are comfortable with writing and with existing ICT. Use of voice and video as a means of taking part in these semi-formal democratic forums is rare, despite the fact that radio phone-ins and social networking/video sharing via services such as YouTube are becoming very widely available and used. It seems likely that offering more and livelier ways for users to engage with e-democracy services – through voice and video – is likely to increase use of such services.

Clearly the combination of voice, video sharing and social networking might offer new value for those seeking to promote democratic inclusion on sites such as MySociety, but video sharing and voice is likely to be supported by upgraded DSL services. The real issue with ascertaining the level of incremental value delivered by next generation broadband relates to interactive video communication. Reliable, many to many two way video communication over broadband is not likely to be delivered by copper technology. It is extremely early in the development of e-democracy services, but we can however identify what such services that depend on next generation broadband might be. They might include:

- Video enabled MPs surgeries.
- Use of broadband to open access to committees and to full assemblies of representative authorities.
- The ability to effectively put questions to such bodies through video channels in real time.

Such services, and there would be many more, as the MySociety website demonstrates, are likely to significantly impact democratic processes over the long term. And E-democracy is only one of the facets of social value that are likely to be impacted by next generation broadband. Clearly, cultural understanding, and social inclusion are other areas where more research is needed.

[143] Paul F. Whiteley. March 1995. "Rational Choice and Political Participation. Evaluating the Debate." *Political Research Quarterly,* Volume 48. Issue. 1. Pages 211-233

Whilst there are clear potentialities, the direction of impact is likely to be difficult to derive in conclusive terms. The impact of genuine, any to any, reliable video capability is likely to be a very disruptive technology with quite unpredictable impacts. For example, even among high users of broadband who do use their PVRs to time shift television use, there remains a rump of linear television viewing. It is likely that one reason for this is related to bandwidth: picture quality available via television transmission networks, and reliability of connection is much greater than that currently available via broadband transmission.

As reliability increases with deployment of next generation broadband, it may be the case that on-demand services such as the BBC iPlayer consolidate their position, but it might also be the case that peer to peer video communication and sharing further displace linear viewing in terms of viewer time spent. Those that assume that mass linear services are a key aspect of democratic citizenship might see this fragmentation as problematic. Those that see the mass services as a hindrance are likely to see its erosion as positive in social value terms. The extent to which next generation broadband enhances participation or rather undermines it depends on how it is used.

Some potential ways of understanding the likely democratic impact of next generation broadband are:

- Next generation broadband could undermine democratic communication if its rollout introduces increased inequalities in access, particularly if specific demographic groups (e.g. rural or ethnic minorities) are excluded as a result.
- Benefits to be realised are potentially great, but there is no way at this point to accurately estimate them or give a value of those benefits. It is likely that reliable, usable and universal two-way video services could have an intrinsic benefit in terms of the ability to take part in democratic deliberation, particularly by those groups (less educated, recent immigrants) that are less comfortable with written forms of communication.

5.7.3 Home working and its impact on community and education

Broadband has facilitated home working, and next generation broadband would be expected to enhance and expand the scope for home working via higher and more symmetric file transfer speeds, greater connection reliability, greater capability to support software as a service, greater access to high performance computing and capability to use sophisticated applications including high definition video collaboration and visually rich content e.g. X-rays, video editing and computer modelling including visualisation software.[144]

Greater scope for home working could lead to better outcomes in relation to educated citizens and belonging to a community. It might also contribute to greater social resilience in terms of the capability of society to withstand shocks and maintain civil society and social capital, and may also reduce the likelihood of large shocks (for example, by helping to limit the spread of an influenza pandemic or reducing the incentive to disrupt transport services).

Some of this value would be reflected in individual private value – either via payment by the employer or employee – including a degree of internalisation of costs and benefits within the family unit since, for example, most parents care about outcomes for their children. To the extent that parents are

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[144] Though some medical bandwidth requirements may exceed the capability of current GPON. In particular, 3D HD requirements for remote robotic surgery currently requires 1.7 Gbps. http://www.ine.cuhk.edu.hk/I2/web/shiae/HD3D/

aware that their involvement in activities such as learning help their children they are therefore likely to invest in such activities. Nevertheless, such internalisation may not be perfect and will certainly not be uniform – technologies that make it easier for people to be involved in the community and in family life might therefore be expected to produce wider benefits.

5.7.4 Inclusion and disability

ICT has reduced some of the disadvantages associated with disability, for example, by allowing better communication to compensate for reduced mobility and by allowing blind and partially sighted people to use read and use the internet utilising speech synthesis technology.

Next generation broadband would improve the potential for video communication to compensate for reduced mobility, and would enhance communication for those who are deaf or hard of hearing via facial cues and sign language (which require high definition and high frame rates). Figure 5-4 illustrates the use of two-way HD video communications over fibre between a customer and Verizon customer support utilising sign language.[145]

Figure 5-4: Use of sign language over an HD video link

The outstanding quality of the video connection that's possible over verizon FiOS high-speed internet access lets David Shelton's expressive personality light up a room hundreds of miles away.

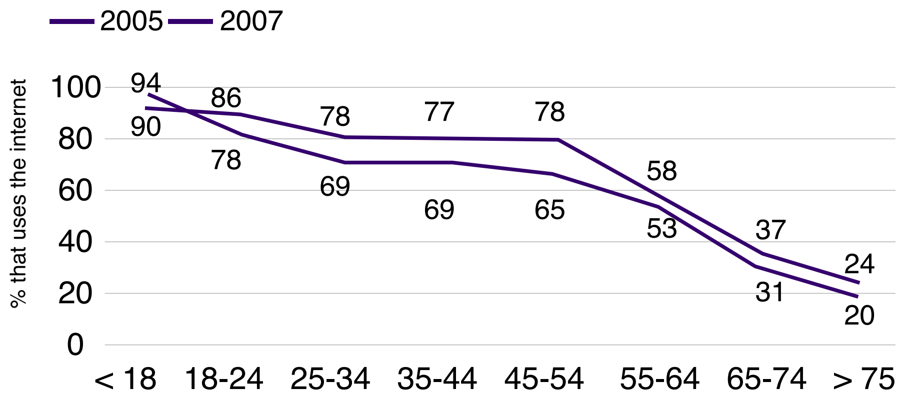
In terms of inclusion, we note that the diffusion of broadband has been very rapid in comparison with most other technologies, and in common with many other technologies initial diffusion tends to be focused on younger, more highly educated richer households – with diffusion spreading to other groups over time. Figure 5-5 shows that age is a key factor in explaining internet usage.[146] Over time one might expect people who use the internet to continue to do so, which will progressively increase overall use.

145 http://responsibility.verizon.com/pdfs/verizon_cr_report_2007.pdf

146 Dutton and Helsper. 2007. "Oxford Internet Survey 2007 Report: The Internet in Britain." Oxford Internet Institute. http://www.oii.ox.ac.uk/research/oxis/OxIS2007_Report.pdf

Figure 5-3

Use by age (QH19 by DQ1)
"In what year were you born?"



OxIS 2005: N-2, 185, OxIS 2007: N-2,350

The OECD have considered internet and broadband use across a range of groups in different countries and reach the following conclusions:[147]

- Broadband penetration is converging on internet penetration, which in turn is approaching PC penetration, though the former is still rising steadily.
- Income: differences in PC and internet penetration by income are decreasing in all OECD countries for which data are available.
- Education: in some countries the gap in terms of internet access between high and low education groups is diminishing (Sweden and Denmark) whereas in others it is not declining significantly (Canada, Korea and the US).
- Age: Older people are less likely to use the internet, but those that do use it have similar or more intense use than younger age groups. Analysis for Canada underline that people do not stop using the internet as they age.
- Children in the family have a positive impact on PC and internet diffusion and broadband access among households.
- An analysis for France across age, income, education, profession and size of agglomeration shows one of the most rapid declines in inequality of possession over time – even faster than mobile phones.

Over time various divides are closing, and may be doing so more rapidly than was anticipated. For example, in the UK rural broadband take-up (59 per cent of households) has overtaken that in urban areas (57 per cent of households).[148] This both suggests that a wide range of consumers are finding value in broadband, and that barriers to access are reducing.

Nevertheless, inequality of access remains an important concern. In the short to medium term this issue is likely to be best addressed by encouraging and/or enabling the take-up and use of current

[147] OECD. December 2007. "Broadband and ICT access and use by households and individuals." http://www.oecd.org/dataoecd/44/11/39869349.pdf

[148] Ofcom. May 2008. "Nations and regions." http://www.ofcom.org.uk/research/cm/cmrnr08/

generation broadband. There may also be a role for FTTC in addressing "not spots" where line lengths are too long to support broadband service. However in the long-term equality of access to next generation broadband could become a matter of wider concern, particularly if next generation broadband delivers growing benefits from which some are excluded.

5.7.5 Social capital, resilience and trust

Next generation broadband would enhance social resilience to the extent that it enhances economic reliance – discussed in Section 3.5.7 (since the capacity of the economy and society to adapt to shocks is linked).

A particular example that illustrates this is the potential benefit of next generation broadband in managing and reducing the impact of a pandemic. Analogous with the argument for public vaccination the benefits of reducing the impact of infectious disease are greater than the private benefits since individuals do not necessarily factor in the benefits to others of reducing their own risk.

The potential to create "social distance" on a temporary basis, to keep citizens informed and to offer a form of remote "triage" could reduce the impact of a pandemic such as influenza (or other pandemics such as SARS or a bio-weapon). **Box 5-3** sets out the reasoning in relation to this.

Box 5-3: Potential benefits from pandemic management

The UK has undertaken planning concerning a future influenza pandemic.[149] Ways in which broadband may facilitate improved pandemic control for both prevention of infection and dampening down the peak intensity of the pandemic, are considered below. The rationale for some of these is the historical evidence on the value of social distancing in pandemic influenza control.[150].

The use of video-communication could reduce the need for business people to travel to pandemic-affected countries (which may delay the arrival of the pandemic in the UK and give more time for vaccine development and other preparations). Further, the feasibility and acceptability of closing educational facilities would be greater if students could continue to be taught in virtual classrooms. The feasibility and acceptability of closing workplaces would be enhanced if next generation broadband enhanced the scope to work effectively from home. In general, the feasibility and acceptability of instituting a wide range of social distancing measures (e.g. reducing the number of public gatherings, cinema and church attendance) would be higher if there were viable online alternatives.

To the extent that next generation broadband access facilitates improved overall access to the internet then this would provide opportunities for citizens to have access to health protection resources online e.g. high quality information on the value of personal hygiene, use of masks.[151]

Next generation broadband could also assist with appropriate diagnosis and treatment by allowing virtual home visits by general practitioners. This would help GPs to determine who most needed hospitalisation, given that UK

[149] Department of Health. 2007. "Pandemic Flu: A national framework for responding to an influenza pandemic." http://www.dh.gov.uk/en/Aboutus/MinistersandDepartmentLeaders/ChiefMedicalOfficer/Features/DH_4102997

[150] Markel H, Lipman HB, Navarro JA, Sloan A, Michalsen JR, Stern AM, Cetron MS. 2007 "Nonpharmaceutical interventions implemented by US cities during the 1918-1919 influenza pandemic." *JAMA*; Volume 298. Issue 6. Pages 44-54.

[151] Jefferson T, Foxlee R, Del Mar C, Dooley L, Ferroni E, Hewak B, Prabhala A, Nair S, Rivetti A. 2008. "Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review". *British Medical Journal;* Volume 336. Pages 77-80.

hospitals may become overloaded during a pandemic.[152] It would also reduce the risks of disease spread within primary care settings. The increased capacity for home monitoring may allow for early discharge from hospital.

Whilst there would be a range of benefits from a reduced incidence of death, disease and disruption arising from a pandemic, the value of a reduction in mortality is in principle straightforward to value. Reductions in transport deaths are valued at around £1 million per death avoided (though a pandemic would differ in terms of the demographic mix of mortality). A major influenza pandemic might produce mortality of around 0.6 per cent,[153] pandemics have a frequency of 2-3 per century (major pandemics have a lower frequency, say 1 per century), so for a population of 65 million the expected annual cost of mortality is £3.9 billion per annum allowing for the probability of a pandemic. If mortality could be reduced by 5 per cent the annual benefit in terms of deaths avoided would therefore be around £200 million. However, the economic, social and psychological dislocation from a pandemic would differ fundamentally from the costs arising from an equivalent number of independent deaths spread over time.

Next generation broadband may also enhance social capital and trust by facilitating video collaboration – a form of communication that conveys identityand allows non-audible cues to enhance understanding. [154]

5.8 Overall conclusions regarding costs and benefits

Our cost and benefit estimates are necessarily incomplete. Where we have not provided a quantitative estimate – and these are primarily illustrative of the overall framework – we have provided qualitative judgements. Overall we conclude that there may be substantial benefits, particularly in the medium term, to offset against the costs of next generation broadband.

Whilst our benefit estimates assume an FTTH network, substantial benefits might be achieved at lower cost and more quickly via an FTTC deployment. However, the right choice of technology is best left to the private sector in an enabling environment where potential barriers to investment are removed, including possible barriers to the replacement of copper by fibre that would lower operating costs compared to running two networks in parallel.

However, not all of these benefits are likely to be realised without complementary changes to policy and the way that we do things. Further, not all of the benefits that are realised will be available to support private investment. In terms of timing, we conclude that there may be benefits to delaying large scale deployment in the short term, and costs in the medium term. The reason for this is that the resolution of uncertainty in the short term will facilitate improved choices.

In relation to coverage, the commercial case for investment will be more difficult to make once coverage exceeds a certain level – particularly beyond towns and cities that comprise around 80 per cent of the population in the UK. Whilst other issues relating to digital inclusion are likely to be more pressing in the short to medium term, the question of whether we value near universal coverage

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[152] Menon DK, Taylor BL, Ridley SA. October 2005. "Modelling the impact of an influenza pandemic on critical care services in England." *Anaesthesia*; Volume 60. Issue 10. Pages 952-954.

[153] McKibbin and Sidorenko. February 2006. "Global macroeconomic consequences of pandemic influenza." Lowry Institute for International Policy. http://www.lowyinstitute.org/Publication.asp?pid=345

[154] OECD. March 2008. "At a Crossroads: "Personhood" and Digital Identity in the Information Society." http://www.oecd.org/dataoecd/31/6/40204773.doc

sufficiently to justify the expenditure involved will need to be considered at some point. Table 5-5 summarises our findings in relation to costs and benefits.

Table 5-5: Indicative estimates of incremental costs and benefits for 80 per cent FTTH coverage

Private	Wider economic	Wider social
Private costs Approximate range for fibre deployment utilising a mix of FTTH and FTTC to 80 per cent of households with a range of take-up for FTTH of up to 100% is £5-£16 billion FTTH with replacement of copper around £9 to £12 billion – allowing for operating cost savings of 30% to 50% £0.8 billion cost in terms of consumer time for installation **Private benefits** (including benefits to government services): (i) Time saving £900 million pa if save 3% of time online for 50 per cent of users (based on leisure opportunity cost of time of £5.50 per hour) (ii) Doing more Online backup £170 million pa (+++) Other – in particular uploading (iii) New things and transformations £320 million pa from online video distribution £190 million pa time savings from 10% less business flights £620 million pa from line server for SMEs (+++) Other new things such as HD 2-way consumer video – positive but not quantified "Short tail" mobile network	**Non-appropriable private** Potential £5 billion from spectrum efficiency in long term (+) Leased land and buildings **Externality** (+) for reduced traffic congestion and GHG emissions once built, (-) during build **Piracy** (?) **Network effects** (+) for 2-way video in particular **Spill-over and virtual agglomeration effects** (+++) large benefits of agglomeration without agglomeration **Competition** Neutral, potentially negative, for telecoms market (++) for wider economy **Resilience, adaptability and policy options** (+++) **Excess burden of taxation** (-) if public funding for investment	**Educated citizens** (++) in relation to lifelong learning, health information etc **Informed democracy and freedom of expression** (+) **Cultural understanding** (?) **Belonging to a community and inclusion** (++) large in relation to inclusion for disabled and hard of hearing **Privacy** (?) **Social capital, resilience and trust** (++)

6 Conclusions and recommendations

6.1 Framework and analysis

The primary aim of this study was to develop a framework for considering the incremental costs and benefits of next generation broadband. To do this, we needed to develop a clear view of the capability of a next generation broadband network relative to existing networks.

We concluded that there is limited scope to improve the capability of the copper fixed line network on a wide area basis (assuming current line lengths), whilst fibre would offer a substantial improvement in capability across a number of attributes of value to users including speed in both directions, consistency of performance and reliability. We are more confident of this conclusion regarding the capability for FTTH than FTTC – further work is required to gain a good understanding of FTTC.

In developing our analytical framework we distinguish private, wider economic and wider social costs and benefits. In general, we have treated a wider set of benefits as private than some other studies, including the BSG study "Pipe dreams?" published in 2007. In particular, we treat many of the potential benefits in terms of government services as private. Within our broad categories – private, wider economic and wider social – we have sought to identify generic "buckets" where costs and benefits might arise – irrespective of whether we are able to estimate costs and benefits.

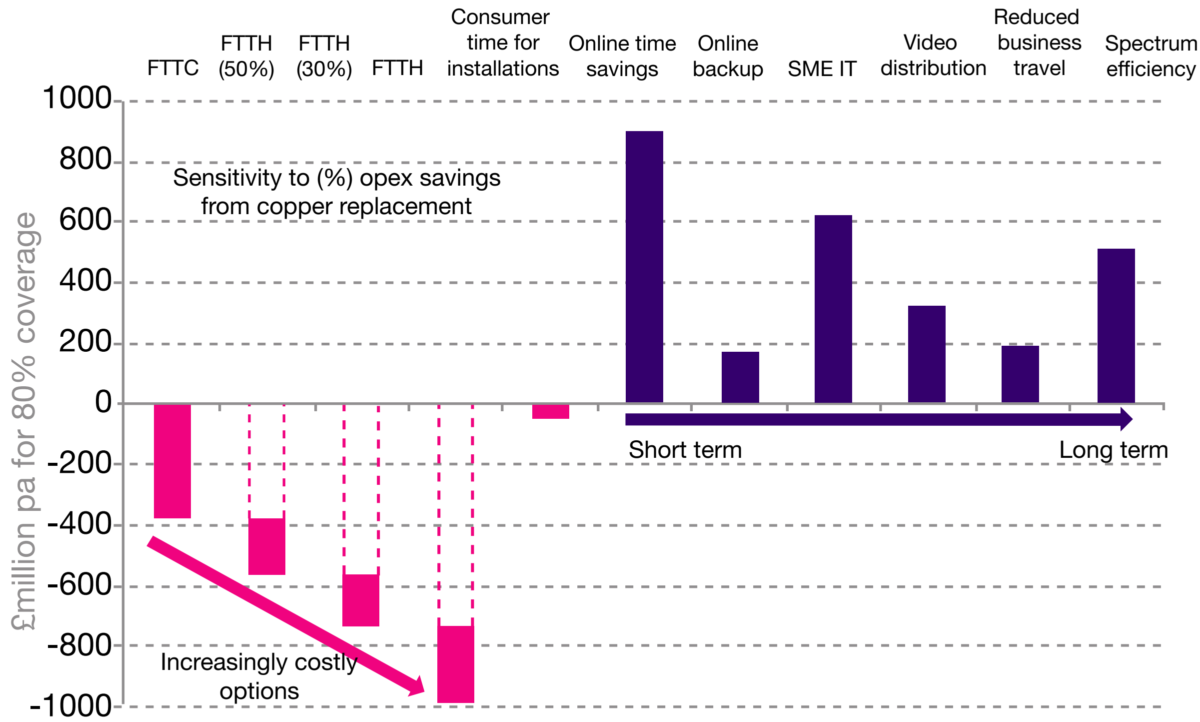
In relation to costs, we consider the costs of building a next generation network, and the potential operating cost savings that would be associated with replacing the existing copper network with a fibre network. In relation to the latter we set out the results of calculations assuming that 30 and 50 per cent of operating costs could be saved.

Three categories of potential economic benefit that we did not quantify appear particularly important, namely spill-over and virtual agglomeration benefits, competition, and economic resilience, adaptability and policy options.

The first of these refers to the potential for next generation broadband to provide a partial virtual substitute for proximity and local network effects – thereby potentially achieving the productivity benefits of cities and other clusters without the need to get more people to live and work in such agglomerations. The second reflects the scope for next generation broadband to expand the scope for trade in services, and therefore to increase the overall level of competition and innovation in the economy. Whilst we assume that competition in the telecoms market is maintained during the transition to next generation broadband, achieving this outcome will require focused industry and regulatory effort. Third, next generation broadband might also deepen supply chain linkages and open up new substitution possibilities within the economy, thereby increasing resilience to shocks such as an oil price shock. Greater economic flexibility is also likely to expand the feasible set of policy options.

Turning to wider social costs and benefits we considered educated citizens, informed democracy and freedom of expression, cultural understanding, belonging to a community and inclusion, privacy and social capital, resilience and trust. Whilst next generation broadband, like any other technology, is likely to generate positive and negative wider social impacts, we concluded that there would be likely to be a number of positive impacts and few negative impacts. On the following page we summarise the costs and benefits we have quantified alongside a qualitative assessment of categories of costs and benefits we have not quantified. The graph and table should be interpreted together.

Indicative incremental annual costs and benefits



Qualitative assessment of other incremental benefits (+) and costs (-)

Scale	Private	Wider economic	Wider social
(+++)	Un-quantified increase in existing activity Un-quantified new things	Resilience, adaptability and policy options Spill-over and virtual agglomeration benefits	Social capital, resilience and trust
(++)		Competition in wider economy	Educated citizens Belonging to a community
(+)		Value of leased exchange land and buildings Reduced traffic congestion Network effects	Informed democracy
Neutral-unclear		Piracy Competition in telecoms Greenhouse gas emissions	Cultural understanding Privacy
(-)	Core network enhancement Costs of transition from copper to fibre with copper replacement Any change in operating costs associated with FTTC or FTTH overlay	Traffic congestion and other disamenity during fibre build Excess burden of taxation for public funding	

In interpreting the preceding chart and table it is important to note that:

- The investment costs shown are for alternatives and a single investment option (in magenta) and should be compared with other costs and benefits (in purple).
- Lump sum costs and benefits (investment costs, consumer time for installation and spectrum efficiency) were converted to equivalent annual flows to allow comparison with other benefits.
- Costs and benefits arise at different times with the short term towards the left and the long term towards the right of the chart.
- All benefits are estimated assuming FTTH. Whilst the benefits with FTTC would be smaller we have not estimated by how much since the UK capability of FTTC is currently unknown.
- Whilst the qualitative benefit-cost is not intended to be precise (+++) could be thought of as of similar importance to larger bars on the chart.

Overall, we consider that there are likely to be substantial benefits associated with next generation broadband in the medium term. However, some of these are dependent on putting in place a framework that enables value to be realised. Doing so should be a priority even if significant investment in next generation broadband is not envisaged in the short term since the decisions that must be taken are long term ones, planning may start early and inefficient plans and decisions might otherwise be developed and taken.

Having identified overall costs and benefits we now consider three questions: what is the value of greater coverage; what is the benefit of FTTH versus FTTC; and what is the cost of waiting.

6.2 Incremental impact of different levels of coverage

We assume 80 per cent coverage in our scenario. This is approximately the proportion of UK households located in towns and cities and also roughly corresponds with the footprint of unbundled local telephone exchanges in the UK. An important question is what costs and benefits might arise with more, or potentially less, coverage.

In terms of private costs, our understanding is that these increase significantly for an extension of next generation broadband beyond towns and cities (i.e. beyond 80 per cent coverage). However, the costs of network extension may fall if costs of next generation broadband fall and long reach fibre become feasible. Willingness to pay may also grow, improving the commercial case for extension.

During the transition to next generation broadband some communities will necessarily gain access to it before others. This will result in relative disadvantage for most communities initially. However, communities and individuals that remain beyond the reach of commercial deployment in the long-term would be disadvantaged, to the extent that next generation broadband has incremental value.

Experience from first generation broadband suggests that geographic inequalities will become a significant issue. At some point, if next generation broadband is delivering significant benefits to users, it is likely that the costs and benefits of extending coverage beyond commercial rollout will need to be addressed.

6.3 Incremental benefits of FTTH over FTTC

FTTC could in principal deliver sufficient bandwidth to support many applications. However, given that we do not currently have good estimates of the likely capability of an FTTC deployment in terms of bandwidth (up and down), consistency and reliability for the UK, the incremental benefits of FTTH over FTTC are difficult to judge.

Some applications, and in particular the capability to run a number of applications simultaneously, may be unique to FTTH. Further, the high degree of assurance in relation to performance provided by FTTH means that the scope to credibly offer differentiated service packages with different bandwidths and to market them may be greater, thereby increasing private investor benefits for a given level of willingness to pay.

6.4 Late versus early deployment

The option to wait exists alongside the option to invest now. Waiting may be valuable if net benefits are expected to rise over time or if some existing uncertainties over costs and benefits might be resolved – which might then lead to a decision to invest or wait longer. Therefore, the investment decision rule is not whether the net present value is greater than zero, but whether it is greater than the value of waiting. This also leads us to reframe the question “what is the cost of delay?”, as the value of delay may be positive in the short term even if the expected value of the investment is positive.

We consider that there is a large option value attached to waiting over the short term. In the medium term, this (option) value might decline as constraints on realising value are removed and as some existing uncertainty over costs and benefits is resolved. In relation to the question regarding the costs of delay, our analysis points to the possibility that delay would be beneficial in the short term and costly in the medium to long term.

6.5 Suggestions for further work

Our analysis raises a number of issues in relation to the costs and benefits, and potential barriers to the realisation of value, in relation to next generation broadband. In particular:

1. Realising the full value of next generation broadband depends on the extent of transformation of other markets. In considering the private and wider value of next generation broadband, and potential regulatory and public policy barriers to next generation broadband, other platforms and markets should be considered including spectrum, broadcasting, mobile and copper networks. In particular, the costs and benefits of copper network retirement alongside fibre rollout, and the policy and regulatory environment required, should be considered.
2. Costs and benefits in terms of consumer convenience and the value of individuals’ time should be considered in assessing ways in which government services might be enhanced via next generation broadband.
3. The linkages between transport and communications as enablers of economic development, and the role of communications technology as a complement and substitute for transport (via home

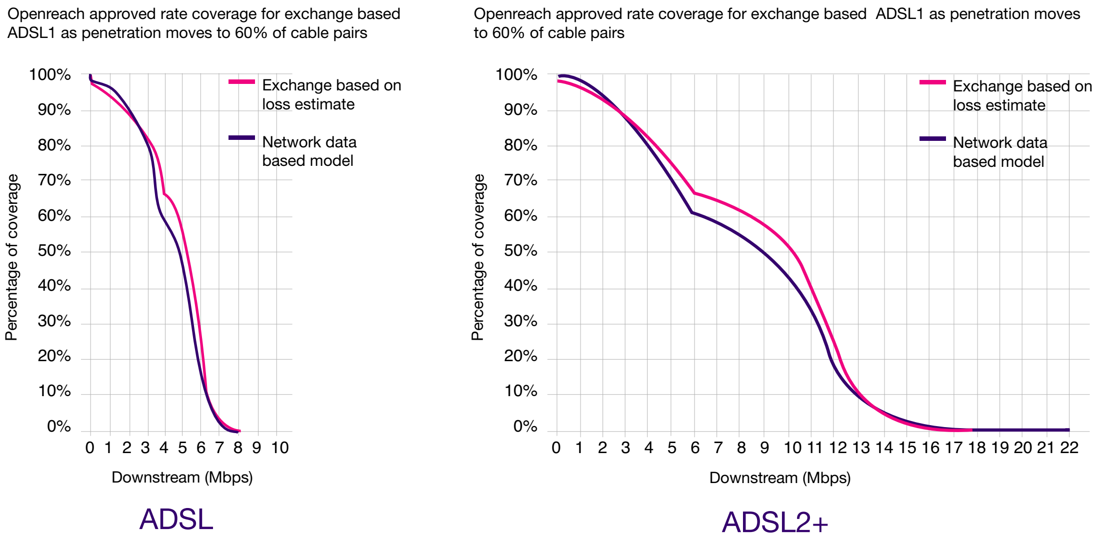
working, telepresence and collaboration tools) should be explored with a focus on virtual agglomeration benefits. This could be integrated with follow up work to The Eddington Transport Study by the Department for Transport.

4. The scope for next generation broadband to mitigate (via "social distance") and help manage a pandemic via information and remote consultations could be explored.
5. The anticipated capability of FTTC, and the uncertainty surrounding it, should be evaluated.
6. Research could be focused on better understanding how people use the internet, their allocation of time across activities including waiting and how their behaviour may be constrained by currently available bandwidth.

Appendix A: DSL over copper

The performance of the copper network depends on a number of factors, in particular the length and quality of the copper line and cross talk due to radio frequency interference between broadband lines.[155] Figure A-1 shows the distribution of line speed performance with the current ADSL technology and with ADSL2+. The results are modelled results.

Figure A-1: Speed distribution with current and proposed DSL technology



We note that Figure A-1 shows frequency distributions. Some readers may be familiar with plots of theoretical speed against line length for ADSL and ADSL2+, possibly with a scatter plot of actual performance data superimposed (which shows wide variation compared to the theoretical potential). In Figure A-1 at least some of the variability in performance – that due to cross talk (radio frequency interference) between lines – is modelled and reflected in the distributions. The line speed distributions are calculated using modelled line length and measured line length and Openreach are working to refine and reconcile the estimates. Table A-1 summarises these results.

Table A-1: Line Performance of ADSL and ADSL2+

	Upstream	Downstream	
	ADSL & ADSL2+	ADSL	ADSL2+
Headline speed capability	0.8 Mbps	8 Mbps	24 Mbps
Median speed	0.7 Mbps	5 Mbps	9-10 Mbps
Minimum speed available to 90 per cent of users	NA	2 Mbps	2.5 Mbps

Note: The table shows national average estimates and estimated performance would vary region by region depending on the distribution of line lengths.

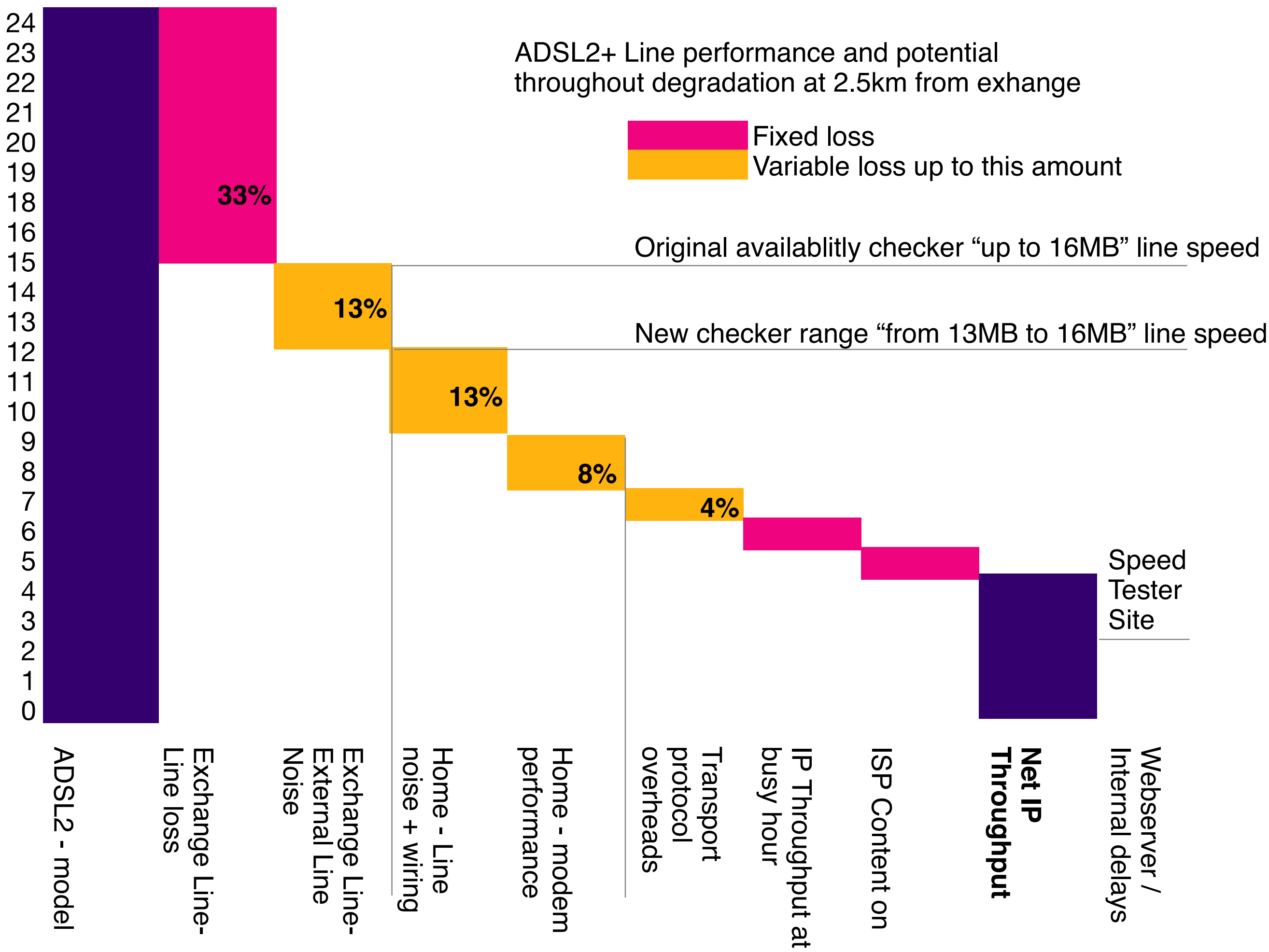
It is apparent that most consumers would expect line speeds well below headline rates of 8 Mbps with ADSL and 24 Mbps with ADSL2+. Indeed, the median line speed offered is around 5 Mbps with

[155] A home modem that is on constitutes an active line. However, turning home modems off (as about a third of users currently do) leads to an overall deterioration of performance since the switching of modems off and on creates erratic intermittent interference that is harder to eliminate.

ADSL and 9-10 Mbps with ADSL2+. Upload speed varies less and the median of around 0.7 Mbps is very close to the peak and identical for both ADSL and ADSL2+. The minimum download speed available to 90 per cent of subscribers, an important consideration in terms of value when considering the economics of services and network effects, is around 2 Mbps for ADSL and 2.5 Mbps for ADSL2+.

The assumption regarding the impact of cross talk reflected in the above table is conservative, but other factors that can degrade performance including external radio frequency interference, customer premise wiring and differences between customer and exchange modem equipment are not factored into the above estimates. Figure A-2 provides an indication of how such factors can impact on end user experience (note that the figure shows the impact for a line length of 2.5 km).[156]

Figure A-2: ADSL2+ line speed and factors affecting performance



Access lines speeds over existing line lengths might improve further in future, though there are constraints in terms of the underlying physics on what can be achieved. Ofcom research on the theoretical limits of copper in the last mile concluded that the upper bound data rate for 50 per cent of

[156] Colin Annette (Director Portfolio and Planning, BT Wholesale). 28 February 2008. "Getting the most from an imperfect access world." 2nd Annual Investing in Broadband in the Access Network Summit. http://www.globaltelecomsbusiness.com/pdf/BT-Wholesale-ColinAnnette.pdf

lines in the UK would be 22 Mbps or more (shared in both directions compared to a median for ADSL2+ of 10-11 Mbps considering downstream and upstream).[157]

[157] Ofcom. May 2008. "Tomorrow's wireless world." Page 57. http://www.ofcom.org.uk/research/technology/overview/randd0708/randd0708.pdf

Appendix B: Wireless

Wireless technologies have a number of different roles in the content of next generation broadband:

Mobile broadband potentially provides a substitute for wired connections, for data, voice and/or TV services; and wireless access could potentially provide a cost effective substitute for fibre in some locations.

- Wireless in-home distribution systems complement next generation broadband by supporting next generation broadband speeds and reliability. In-house wiring may not be capable of operating at next generation broadband speeds/reliability or in some cases may not exist.[158]
- TV delivered over next generation broadband is a substitute for terrestrial and/or satellite networks.

Below we discuss developments in mobile broadband, wireless in-house distribution, broadcast TV services and wireless broadband access and their implications. The key points are as follows:

- Demand for mobile broadband is growing rapidly. Anticipated technology developments, together with the release of more spectrum for mobile applications and the construction of denser networks, will facilitate the move from 3G to 4G and to much higher capacity (possibly up to 50-100 Mbps). In addition mobile TV could enhance mobile broadband capacity in the near term. Wireless is not a substitute for fibre in terms of capability (as it is necessarily contended), but it will be a substitute for some (perhaps many) users.
- Wide area fibre would support evolution towards dense wireless networks with WiFi distribution in the home/office. WiFi speeds of around 50 Mbps are already possible at 2.4 GHz and 5 GHz and higher speeds are anticipated with the further development of 802.11n. Products incorporating the latter are already in the market and are expected to be upgraded in the next few years.
- Terrestrial broadcasting cannot support a multiplicity of HDTV channels and has limited interactive capability, and so its long term future is doubtful. If cable, satellite and next generation broadband transmission increasingly substitute for terrestrial services there will be the possibility of a terrestrial TV switch-off. This could release up to 256 MHz of spectrum for alternative, probably mobile, applications. Recent trades and auctions in the US suggest this spectrum is very valuable today and there are good reasons to expect this to continue given growth in mobile data services.
- Switch-off of terrestrial TV would require not only a set of market conditions in which broadcast TV is a less important entertainment and information medium than at present but also a number of complementary policy interventions. Policy intervention may also be required to replan the spectrum released by switch-off to make it useful for other services. Replanning could be difficult to achieve if there is license-exempt use of the interleaved spectrum e.g. for in-home wireless.
- There could be a role for wireless as part of next generation broadband, but this is likely to be limited to specific locations, probably in urban environments, because only short range/high frequency wireless links are likely to offer the capacity required to support high speed (over 10 Mbps) broadband.

[158] If the modem is by the PC there may be little internal data cabling. Where data cable (Cat 5) has been installed it should have sufficient bandwidth to support distribution of NGA based services. We note Verizon wireless routers are bundled with its next generation broadband product.

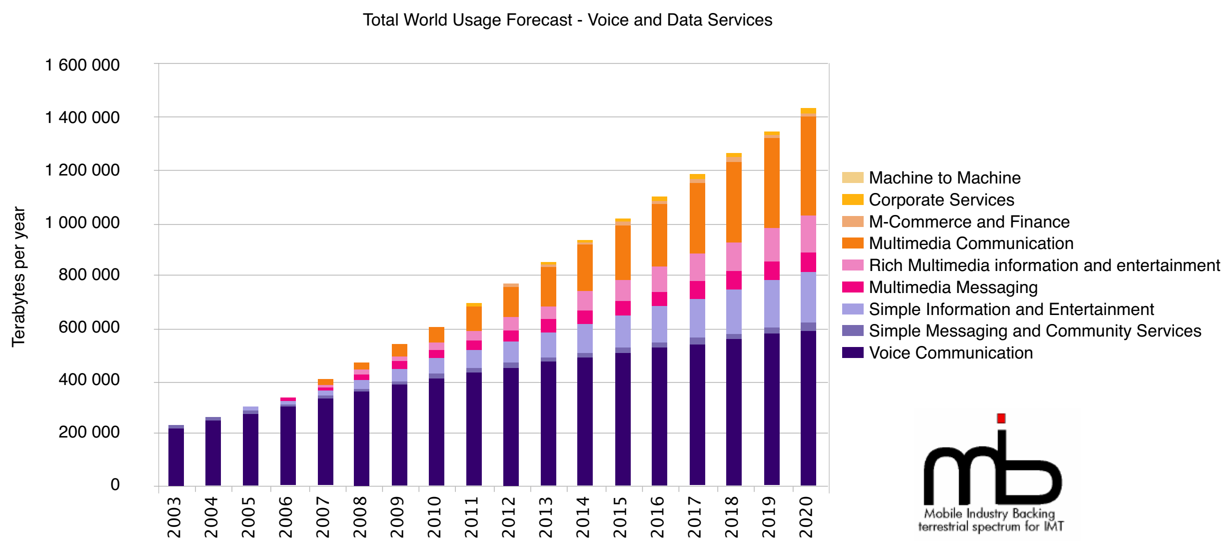
- In rural areas 3G using 900/1800 MHz spectrum (and possibly in time UHF spectrum) could provide high levels of coverage because this frequency range provides good wide area coverage without the need for a dense infrastructure.
- Satellite services could provide even greater coverage but this is likely to be at a higher cost than 3G, suggesting that in the UK satellite broadband services will be a niche service aimed at consumers/businesses/communities with few if any other broadband access choices.[159] In this regard satellite technology has been advanced as providing part of the solution to digital divide issues. A study by the European Commission found that "*Satellite services are likely to be optimal in very isolated areas, in areas with difficult topographies, or as a medium term provision when terrestrial roll-out is uncertain*."[160]

B.1 Mobile broadband

B.1.1 Demand

Cisco forecasts that in Western Europe mobile data traffic will grow by around 50 per cent per annum over the period 2006-2011 and 65 per cent per annum in North America. The ITU similarly forecasts very strong growth in mobile data (see **Figure B-1**) over the period to 2020.[161] The higher growth rates in the US are partly a result of better 3.5G network coverage.

Figure B-1: ITU Forecasts of World Mobile Traffic Growth 2006-2020



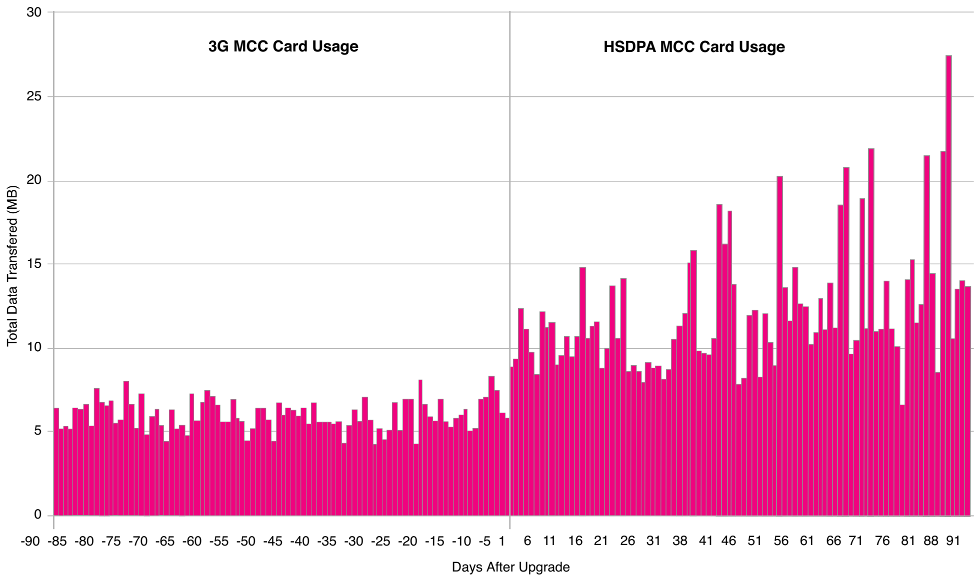
Source: Report ITU-R M .2072 - World mobile telecommunication market forecast, (chapter 6.2.3, results from France Telecom)

[159] http://www.esoa.net/v2/docs/public_spacePolicy/20070615_ESOA_BroadbandSatellitesForOECD.pdf

[160] European Commission. 2006. "Digital Divide Forum Report – Broadband access and public support in under-served areas." Commission Staff Working paper, SEC 354. http://ec.europa.eu/information_society/eeurope/i2010/docs/digital_divide/sec_ddf_report.pdf

[161] Market growth calls for more mobile spectrum, 8 January 2007. http://standards.nortel.com/spectrum4IMT/MiB-Slides__markets%20call%20for%20more%20spectrum.pdf

Figure B-2: Change in Data Traffic as a Result of introducing HSDPA



As can be seen, the customers' experience of higher data rates would appear to have led to an increase in traffic levels (even though customers were not told about the change).

In addition to the expanding coverage of high capacity networks, traffic growth is likely to be stimulated by attractive price plans allowing high levels of monthly usage, plug and play dongles and the inclusion of HSDPA functionality in all new 3G mobile handsets.

Mobile broadband could in principle provide a substitute for fixed broadband, just as it does for voice services. In the UK around 10 per cent of households are mobile only. It can be expected that in future there will continue to be some households who have either relatively low bandwidth demand, are highly mobile or whose broadband use is primarily outside the household and for whom mobile services are sufficient.

In addition, mobile TV services are being launched in many countries, to provide broadcast video services to mobile handsets, as to accommodate broadcast services within existing 3G networks would require MBMS technology and a large proportion of the mobile spectrum to provide a reasonable selection of channels. Mobile TV provides a potential substitute for fixed TV, however, the evidence from pilot studies suggests it is only a weak substitute and it may be packaged differently e.g. more trailers and highlights.

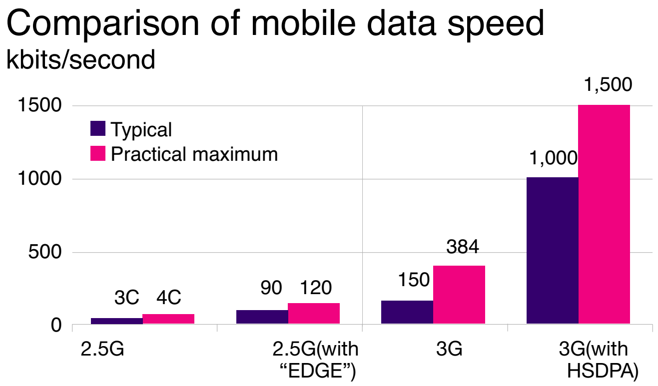
B.1.2 Technologies

Mobile networks will be upgraded using more efficient technologies. The near term WiMAX and 3.5G services (see Figure B-3) will be deployed together with higher speed WiFi networks (see Table B-1 in Section B.2) for access in hotspot locations. Development of 3G mobile and WiMAX services will provide DSL customers with alternative broadband access options, potentially at lower cost for some users, who may then drop their fixed line. Both 3G and WiMAX will in future have greater upload capability than DSL, and in the case of WiMAX the balance between upload and download capability

[162] Lee McDougall. October 2007. "Customer Led Deployment." Vodafone UK, presentation at Cannes.

can be set by the operator. However, the capacity of a mobile or WiMAX base station is shared between users (i.e. typically 2 Mbps peak throughput is shared with a contention ratio of 20:1 to 50:1), whereas with ADSL each user has direct access to up to 8 Mbps with the contention occurring higher in the network. The impact in wireless systems is greater because it occurs over the air interface. This limits the ability of wireless networks to support streaming services where constant throughput is necessary.

Figure B-3



Source: GSM Association

In the longer term (10+ years time) mobile networks are expected to evolve to all IP networks potentially offering high upload (50 Mbps) and download (100 Mbps) speeds while on the move[163] and more when stationary. This may be achieved using a number of different access technologies. There are however physical limits to the growth in data rates that can be achieved without significantly decreasing the range of transmissions.[164] To support these higher data rates, frequencies above 2-3 GHz will have to be used implying the need for considerable investment in a dense network of transmitters in urban areas and to provide good indoor coverage.[165] In this regard we note that most of the increase in the capacity of mobile networks is the result of investing in dense infrastructure, which means more capacity is available to users in a given area as a result of greater spectrum reuse.

More radio spectrum provides a partial substitute for investment in additional infrastructure. Some of the growing spectrum requirement for mobile broadband will be met by refarming 900/1800 MHz bands from 2G to 3G and release of the 2.6 GHz band but additional spectrum could be required. At the 2007 World Radio Conference co-primary allocations for the expansion of mobile services in Europe were agreed for UHF and in the 3.4-3.6 GHz bands. In the longer term, frequencies in the 2.7-3.4 GHz and 4 GHz ranges may be considered. The UK is leading the way in seeking to make these frequency ranges available to the market through auction on a technology and service neutral basis.

[163] http://www.3gpp.org/Highlights/LTE/LTE.htm

[164] William Webb. 2007. "Wireless Communications: The Future." John Wiley and Sons.

[165] Higher data rates are typically associated with shorter transmission distances as higher data rates require more spectrum and more spectrum is typically only found at higher frequency ranges that have shorter transmission distances for a given transmission power.

B.2 In-home wireless distribution systems

A simple, reliable low cost method of distributing the content delivered to/from devices in the home to the broadband network is required. At present many devices (e.g. PCs, TVs) are tethered to a particular location by virtue of the fact that they have a specific wired connection. However, wireless routers/home hubs are available in the market and offer the user a flexible, low cost connection (relative to installing wiring) to the broadband network.[166] Adoption of in-home wireless systems allows more devices (such as games machines and the home automation system) to have a broadband connection and thereby makes the broadband connection more valuable.

The technologies used for in-home wireless distribution include WiFi at 2.4 GHz and 5 GHz, Bluetooth and ultra wideband (UWB). The transmission speeds and ranges for these technologies are shown in Table B-1. Data rates have been increasing over time and while this can be expected to continue there will be a physical limit to the data rates that can be achieved at frequency ranges that allow signals to penetrate walls within the home. Note that all the technologies listed can use all the available capacity for either upload or download, depending on the user requirement.

Table B-1: Performance of In-home Wireless Distribution Systems

	Maximum Throughput and Range	Availability
UWB	480 Mbps at 2m; 200 Mbps at 4m; 110 Mbps at 10m (limited to within room communications)	Devices expected to become available in 2008
WiFi – 802.11a 5.8 GHz	54 Mbps [practical speeds of ~25 Mbps] 35m range indoor	Available now
WiFi - 802.11b 2.4 GHz	11 Mbps [practical speeds of ~4.5 Mbps] 35m range indoor	Available now
WiFi - 802.11g 2.4 GHz	54 Mbps [practical speeds of ~25 Mbps] 35m range indoor	Available now
WiFi - 802.11n 2.4 GHz and 5 GHz	600 Mbps [initial products are 258 Mbps with a practical speed of 74 Mbps] 70m range indoor	Apple has a product available now. The standard will be finalised in 2009
Bluetooth	721 kbps Typical range 10m (limited to within room communications)	Available now

All of these technologies operate on a licence exempt basis and no spectrum shortage is anticipated in the near term, as any congestion at 2.4 GHz could be relieved by use of WiFi at 5 GHz. An issue for next generation broadband is whether wireless systems will have sufficient throughput to allow users to take advantage of the access speeds available (typically 20 Mbps upstream and 50 Mbps downstream), whilst still supporting the communications traffic between other devices within the home.

UWB clearly has the bandwidth capability but the limited range may prevent access to the next generation broadband termination point from all parts of the house. Wi-Fi 802.11a/g has the range

[166] http://www.ofcom.org.uk/research/technology/research/exempt/econassess/annexes6.pdf

but with 25 Mbps typical throughput for both directions, would not be able to extend the full capability of next generation broadband.

Wi-Fi 802.11n is initially expected to extend typical throughputs to 74 Mbps using a combination of better coding, channel combination and MIMO antenna technology.[167] Although 802.11n devices are available for the 2.4 GHz band initially, there are doubts about being able to achieve the higher rates where there is congestion. However, if there is demand for higher capability indoor wireless from next generation broadband users, there will be stimulus to develop similar products in the 5 GHz band. The spectrum at 5 GHz is expected to be sufficient to meet anticipated demand for in-home distribution for the foreseeable future (i.e. at least 10 years).

B.3 Satellite Broadband Access

Satellite broadband services are currently offered across the UK. Existing SES and Eutelsat Ku-band satellite systems (such as SES and Eutelsat) typically can offer between 768 kbps – 1.5 Mbps downloads with 256-512 kbps uploads. However, the penetration of satellite broadband access in the UK is currently very low at less than 0.1 per cent of the total market.[168] This is partly explained by the relatively high total cost of the service, comprising the upfront cost of equipment and its installation and on-going charges, compared with DSL and cable modem services.[169] Also the signal delay associated with geostationary satellite systems could make the service unattractive to users wanting a real-time service.

Avanti's planned Ka-band HYLAS system, which will be deployed in 2009, will be capable of providing between 2-4 Mbps downloads and 512 kbps –2 Mbps uploads. Eutelsat has recently announced a new Ka-band satellite system for deployment in 2011 that should be capable of higher throughput data rates than present generation Eutelsat satellites.

This suggests there could be an opportunity for satellite to address the broadband connectivity market where terrestrial technologies (wired and wireless) are not available or offer low data rates. The ability to address these markets will be dictated by the ability of satellite to deliver a service at an acceptable price and quality of service in order to compete with services offered by various terrestrial wireless systems (e.g. 3G, WiMAX) which also offer mobile functionality and/or wired broadband.

A study by the European Commission found that *"Satellite services are likely to be optimal in very isolated areas, in areas with difficult topographies, or as a medium term provision when terrestrial roll-out is uncertain."*[170] In this regard satellite technology has been advanced as providing part of the solution to digital divide issues.

[167] http://www.wi-fi.org/80211n-draft2.php

[168] Satellite is included in the "other" category in Ofcom data that in H1 2007 accounted for 0.1 per cent of residential and SME broadband connections. Ofcom. 2007. "The Communications Market 2007." Page 262. http://www.ofcom.org.uk/research/cm/cmr07/telecoms/telecoms.pdf

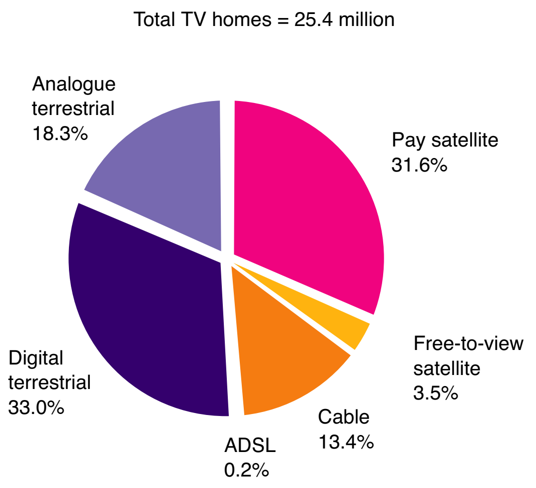
[169] Intellect. "Satellite provision of Next Generation Broadband Services in the UK." October 2007. http://www.intellectuk.org/component/option,com_docman/task,doc_download/gid,2370/Itemid,102/

[170] Commission Staff Working paper. 2006. "Digital Divide Forum Report – Broadband access and public support in under-served areas." SEC 354 http://ec.europa.eu/information_society/eeurope/i2010/docs/digital_divide/sec_ddf_report.pdf

B.4 Broadcast TV

In the UK delivery of broadcast TV is dominated by the two wireless platforms – terrestrial and satellite (see Figure B-4). Over the next four years analogue terrestrial TV will switch-off and most households currently using this platform are expected to switch to digital terrestrial.

Figure B-4: Primary TV set by platform – Q1 2007



Source: Ofcom Communications Market 2007

The terrestrial platform has a significant advantage in terms of the low cost of access for households because of the large installed base of roof top aerials and its almost universal coverage. Looking ahead over the next 10-20 years there are question marks over the continued popularity of the terrestrial platform. This is because of growth in the installed base of HDTV sets and likely strong growth in demand for HDTV services.[171]

Growth in demand for HDTV (and potentially in future 3D TV) is problematic for the terrestrial platform because it has much less capacity than satellite, cable and in the longer term next generation broadband. If MPEG4 compression and the DVBT-2 transmission standard are adopted after switchover on one or more multiplexes then a single DTT multiplex will be able to support 4 HDTV services or 20 SDTV services.[172] While this is a significant (160 per cent) improvement on the current capability of DTT, the platform will still lag behind satellite, cable and next generation broadband in terms of capacity (as they too will deploy advanced compression and transmission standards). Consumers will also need to buy new set top boxes to receive HDTV services on any platform.

In addition the terrestrial platform has the disadvantage that it will have to compete for spectrum with other potentially high value applications, such as mobile TV and mobile broadband i.e. the opportunity cost of using the spectrum for TV could rise and provide an incentive for commercial broadcasters at least to move to alternative platforms (assuming spectrum trading is permitted). The UHF spectrum is particularly well suited to delivery of mobile services because signals travel longer distances and are

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[171] Market research indicates that consumers expect that they will be able to receive HDTV in future. BRMB for Digital UK. 23 February 2007. "Research on public expectations of High Definition TV."

[172] Ofcom. April 2008. "Digital television – enabling new services." http://www.ofcom.org.uk/consult/condocs/dttfuture/statement/statement.pdf

able to penetrate buildings better than higher frequency ranges both of which imply reduced network costs and better service coverage. [173]

Furthermore, if as expectedconsumers increasingly demand access to content when they want it rather than when it is broadcast to them, interactive platforms such as cable and next generation broadband are likely to be preferred. [174] While a pseudo on-demand service can be offered through download and replay of material on a hard disk limits on the available spectrum at UHF mean even the download options are much more limited compared say with satellite transmission.

All of these factors point towards a scenario in which there is declining demand for broadcast TV delivered over the terrestrial platform in the long term. Extensive next generation broadband roll-out could allow consumers to migrate from the terrestrial platform, assuming (as seems likely) that there is a robust in-house distribution system (wireless or wired) for content received over next generation broadband to enable reception of viewing of video content on numerous screens around the house. Ultimately this might allow further release of UHF spectrum for other uses.

The spectrum occupied by terrestrial digital TV services spans 256 MHz of UHF spectrum, though some of this is used by other services on an interleaved basis e.g. for programme making and special events and other users that will buy access to the interleaved spectrum in an auction scheduled for 2009 (the net value of this spectrum may be lower than indicated by the full 256 MHz if real resource expenditures are required to move incumbent users in the interleaved frequencies not used by digital TV, or if incumbent users remain thereby reducing the spectrum released).

A headline estimate of the value of the entire 256 MHz can be inferred from estimates of the marginal opportunity cost of UHF spectrum in the UK and market data from the US (we note these approaches value all UHF spectrum at the marginal value which underestimates total economic value).

Using the value of a recent US spectrum trade in this frequency range we estimate that a current ball park estimate for the market value of this spectrum is around £8 billion.[175] Another indication of the value of UHF spectrum is the FCC auction of spectrum released by digital switchover, which closed on 19 March 2008 with total bids of just under $19.6 billion.[176] Based on the outcome for block E the US auction provides an estimate of around £6.5 billion for the full 256 MHz of UHF spectrum in the UK.[177] For 80 per cent network coverage the value is around £5 billion, or an annualised value of £500 million per annum. Such gains would only be realisable in the medium to long term, by which time the value could have changed materially. The estimates should therefore be interpreted with caution, and kept under review.

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[173] Delaying the allocation of UHF spectrum to mobile services by 4 years is estimated to result in forgone benefits of €20 billion across the EU. See http://www.spectrumstrategy.com/Pages/GB/perspectives/An-early-allocation-of-UHF-spectrum.pdf

[174] Growing DVR take-up is associated with an increase in time shifting of viewing. In addition some (around 30 per cent) of DVR use is reportedly to skip advertisements. Pages 69-70, 84-87, 108-109, The Communications Market Review 2007, Ofcom.

[175] In October 2007 AT&T purchased a 12 MHz band of 700 MHz frequency spectrum for $2.5 billion. The spectrum covers 196 million people. Allowing for the UK population and exchange rate this equates to roughly £31 million per MHz, or £7.9 billion for 256 MHz. Ofcom have also published estimates of the economic value of radio spectrum http://www.ofcom.org.uk/research/radiocomms/reports/economic_spectrum_use/

[176] FCC. 19 March 2008. http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-280913A1.pdf

[177] This was a block of 1x 5 MHz of unpaired spectrum. It sold for an average price of $0.852/MHz per pop. Multiplying by the UK population and 256, and assuming an exchange rate of $2=£1, gives a total value of around £6.5 billion.

B.5 Wireless broadband access

The potential for wireless broadband access to deliver last mile speeds of 10-20 Mbps was investigated for Ofcom by Plextek.[178] They found that wireless cannot realistically compete with fibre over the whole of the last mile because spectrum constraints limit the capacity available except at very high frequencies. Wireless could however have a role as a feeder element in an urban next generation broadband network e.g. providing transmissions from the cabinet. Plextek identified point to point applications for which equipment already exists and that use abundant spectrum at 60, 70 or 80 GHz. The transmissions would travel from lamppost to lamppost down the road and the final distribution to the house would be made using WiFi at 2.4 or 5 GHz.

A study by Quotient for Ofcom also identified a point to multipoint technology that operates at 40 GHz that could in principle be used to provide high capacity links to households.[179] However, it is unclear whether this is likely to be economic.

We conclude there could be a role for wireless as part of a next generation broadband network, but this is likely to be limited to specific locations probably in urban environments. By contrast in rural areas 3G using 900/1800 MHz spectrum is likely to provide an almost ubiquitous relatively low cost broadband access technology because this frequency range provides good wide area coverage without the need for a dense infrastructure.

[178] http://www.ofcom.org.uk/research/technology/research/ese/lastmile/lastmile1.pdf

[179] http://www.ofcom.org.uk/research/technology/research/exempt/higher/

Appendix C: US evidence in relation to fibre investment

We focus on evidence from the US for several reasons. First, a considerable amount of information is readily available (the investors are publicly listed companies). Second, investment in FTTH and FTTC has been underway for several years and is not subject to price regulation (so pricing plans can be expected to reflect value and willingness to pay). Third, investment is occurring without public funding support and in the absence of a national industry plan or policy.

C.1 Fibre deployment costs

Table C-1: Cost for FTTH and FTTC (US$)

	AT&T[180]	Verizon FTTH[181]			
	2006	August 2006	Year end goal 2006	2008 Sanford Bernstein[182]	2010 Verizon expected
Cost per home passed	300	873	850	817	700
Cost per home connected	550	933	880	718	650

Note: The Verizon FTTH cost estimates include the cost to pass a home, connect a home, install customer premise equipment, including a wireless router, and ensure the service is working satisfactorily i.e. it is the cost to provision a retail service. They do not include the costs of enhancing other elements of the network to support an enhanced access network.

The FTTH cost estimates include the cost to pass a home, connect a home and install customer premise equipment including a wireless router and ensure the service is working satisfactorily i.e. it is the cost to provision a retail service. The Verizon homes passed and connection costs do not include the costs of enhancing other elements of the network to support an enhanced access network, though the overall estimate of $23 billion to pass 18 million homes by 2010 and achieve penetration of 35-40 per cent includes network enhancement costs. Based on changes in installation costs over time we infer that approximately 10-15 per cent of overall costs relate to network enhancement.

AT&T investment costs per home connected are running at around 50 per cent of the costs for FTTH, more than the anticipated 30 per cent. Some of the additional costs for FTTC may, however, relate to requirements to improve the condition of comparatively long residual copper line lengths to achieve desired speeds, and investment in servers and compression etc to allow TV services to be delivered over the more limited bandwidth of FTTC.

The falling costs of FTTH are due to learning and innovation. In particular, time to install is falling, the move to GPON and the adoption of MoCA (Multimedia over Coax Alliance) standard for transporting video and multimedia content around the home via coax cables has reduced costs; and new technologies such as Corning "ClearCurve" bendable fibre are expected to lower costs further,

180 Pers comm. Richard Dineen. January 2008. HSBC. Also provided numbers for Verizon consistent with public figures shown.

181 With the exception of Sanford Berstein column: NetworkWorld. September 2006. "Verizon provides FiOS update." http://www.networkworld.com/news/2006/092706-verizon-fios.html?page=2

182 Sanford Berstein. January 2008. "Economics of FiOS make little sense for Verizon." http://www.multichannel.com/article/CA6524100.html

particularly for installations in apartment buildings. [183] Installation to date has mostly been at suburban densities, and roughly 60 per cent of fibre is overhead with the remainder ducted or buried.

Verizon have said they expect to realize savings of about $1 billion in annual, ongoing operating expenses by 2010, when Verizon expects to pass 18 million homes with fibre and have 6-7 million FiOS customers (Verizon have a fixed line residential customer base of around 30 million). This implies an operating cost saving of $143-$166 per customer per annum. Another near term estimate is $110 per line per annum (Pers Comm HSBC).

Whilst it is standard Verizon practice to disconnect copper when a customer has FiOS installed, these estimates are unlikely to capture the full potential for operating costs savings available if the copper network is shut-down. The gradual phasing out of copper was discussed in 2005 by Verizon:[184]

> *"Once we install fiber to a home, it stays there. We aren't going to take down the fiber and reinstall copper, but people can still get their single-line, no-frills Verizon phone service over the fiber network for the same amount as the folks still served by copper, if that's what they want. Our FTTP network is likely to be even more reliable than their already-reliable Verizon copper-based phone service."*

More recently, the question of shutting down copper lines has become more controversial with the prospect of competitive service providers losing access to copper lines.[185] As at November 2007 the FCC had not opened a procedure in response to a petition to open a rulemaking *"to establish strengthened safeguards to protect against ILEC anticompetitive copper loop retirement*."[186]

C.2 Verizon FiOS (FTTH) service

In the US Verizon charge more for their FTTH service (FiOS) than broadband over copper. They also charge more for higher bandwidth tiers over fibre and have introduced new service tiers and changed their pricing over time. Some basic facts on the FiOS service are presented below:[187]

- Verizon are upgrading from BPON to GPON, offering higher speed capability. FiOS GPON has delivered 2.4 Gbps down and 1.2 Gbps up in tests, though the highest speed commercial plan currently available is 50 Mbps down and 20 Mbps up (with a 32 way split in terms of end users).
- All FiOS speeds are assured and there are no usage caps. FiOS service was launched in 2005 and 10.4 million premises were passed by fibre at Q1 2008, with plans to pass a further 3 million premises per annum (9 per cent) reaching 18 million homes by 2010.

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[183] Corning. February 2008. "Verizon Purchases Corning® ClearCurve TM Cable Solution Following Successful Field Trials." http://www.corning.com/news_center/news_releases/2008/2008020701.aspx

[184] http://www.dslreports.com/shownews/83801

[185] June 2007. "Copper retirement notices stack up." http://www.xchangemag.com/articles/07julfeat06.html

[186] NASUCA letter to FCC. 5 November 2007. http://www.nasuca.org/CopperRetirementExParte11%205.pdf

[187] Verizon. 28 April 2008. "Investor quarterly Q1 2008." Also Q4 2007 and Q3 2007 transcripts. http://investor.verizon.com/news/20080428/

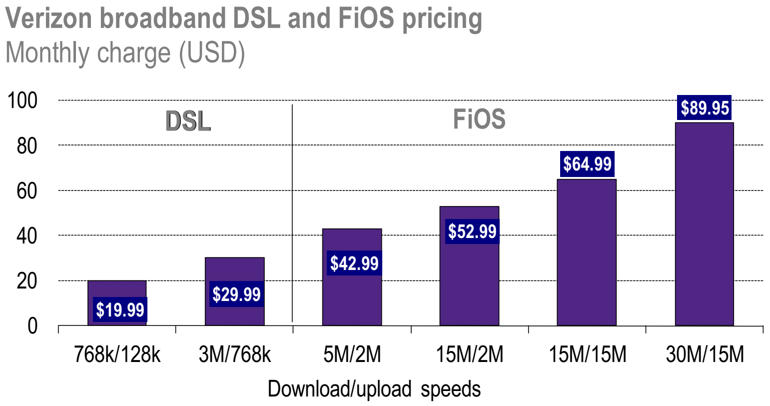
http://investor.verizon.com/news/20080128/4Q07_vz_transcript.pdf

http://investor.verizon.com/news/20071029/3Q07_vz_transcript.pdf

- FiOS broadband service was available for sale to 7.9 million premises and there were 1.8 million subscribers (22.9 per cent penetration and up 109 per cent on a year-on-year quarterly basis). Overall broadband connections were up 14.9 per cent to 8.5 million.
- FiOS TV service was available for sale to 6.5 million homes and there were 1.2 million TV subscribers (1.7 per cent penetration). TV availability lags broadband availability because of the need for local regulatory approval.
- During the December 2007 quarter Verizon added 262,000 net new FiOS internet customers and 4,000 net DSL subscribers.
- Overall the number of access lines declined 8.2 per cent during the past year, ending with 40.5 million. In some locations such as Rhode Island where FiOS is available access lines are increasing.
- A symmetric 20 Mbps service was introduced on 20 November 2007 (the service is 15 Mbps in some locations) to meet Web 2.0 and SME needs.
- Video is carried as an analogue signal over a separate frequency on the fibre, though digital IPTV will be progressively rolled out. HD video on demand was launched on 5 December 2007.
- Network faults requiring maintenance dispatches for those on FiOS showed an immediate decrease of 80 per cent from 1 per cent to 0.2 per cent when compared to dispatches for legacy architectures in the same regions.

The range of plans available are illustrated in Figure C-1 (7 Mbps DSL is not listed by Verizon).[188]

Figure C-1



Source: Plum Consulting. www22.verizon.com. Pricing for one-year contracts.

Whilst we do not have precise information on the take-up of each plan, a number of factors point to consumer willingness to pay for higher speeds across the range of offers:

- Pricing, and current and anticipated take-up of FiOS (35-40 per cent by 2010) imply a margin in terms of willingness to pay. Whilst some of this relates to TV services, take up of FiOS broadband only and take-up of higher bandwidth FiOS tiers support this conclusion.

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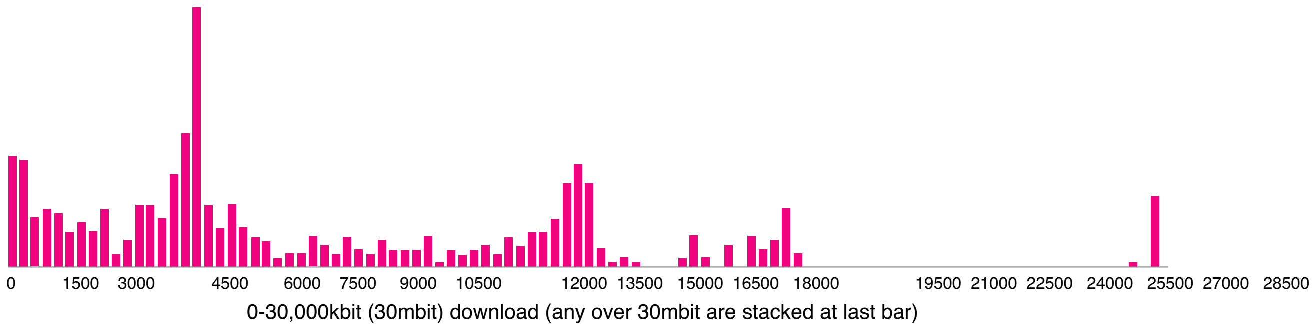
[188] http://www22.verizon.com/content/consumerfios/packages+and+prices/packages+and+prices.htm
In a number of locations a symmetric 20 Mbps package is offered instead of 15 Mbps symmetric.

- The minimum FiOS service is 5 Mbps downstream and 2 Mbps upstream priced at $42.99 per month – a $13 premium over the 3 Mbps DSL plan and a $3 premium over the 7 Mbps DSL plan (available in some locations).
- Verizon have changed the services and price points several times, most recently introducing a 20 Mbps symmetric service (15 Mbps in some States) and raising the price of the 5/2 and 15/2 service tiers by $3 (the price of the 30/15 tier has fallen substantially).
- Approximately 70 per cent of FiOS broadband customers are new to Verizon, and roughly two-thirds of subscribers are cable defectors. 23 per cent of FiOS additions are DSL customers migrating to higher speeds. There is evidence that in three States (New York, New Jersey and Connecticut) 20 Mbps options are the most popular options.[189]
- Broadband and video revenues grew 56 per cent on a year-on-year quarterly basis in the consumer segment, and average ARPU among FiOS customers was approximately $129 per month.
- Evidence on the distribution of speeds available over FiOS from a self selecting sample which shows peaks at 5 Mbps, 15 Mbps and 20 Mbps (see **Figure C-2**). Note that download speeds of 15 Mbps could correspond to 15/2 or 15/15 price plans.

Figure C-2

Customer download speeds for fios.version.net - generated 2008-05-16 12:20:20, for tests last 14 days



C.3 AT&T U-serve (FTTC) service

In May 2006 AT&T announced plans to spend approximately $4.6 billion on its Project "Lightspeed" FTTC initiative to reach nearly 19 million homes by year-end 2008 with enhanced broadband.[190] Subsequently, a rise in costs to $6 billion was announced along with a reduction in planned reach to 18 million.[191] Problems have also been reported in relation to the batteries installed in cabinets: [192]

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[189] Gizmodo. "Next up for Verizon FiOS: Invading Manhattan, Japan-Like Uber-Bandwidth." http://gizmodo.com/tag/verizon-fios/

[190] http://www.att.com/gen/press-room?pid=5097&cdvn=news&newsarticleid=22272

[191] WSJ. 8 May 2007. http://online.wsj.com/article/SB117856112849694724-search.html?KEYWORDS=AT%26T&COLLECTION=wsjie/6month

[192] WSJ. 16 January 2008. "Batteries hamper AT&T effort." http://online.wsj.com/article/SB120045143379793329.html?mod=sphere_ts

"In the latest setback to AT&T Inc.'s effort to roll out an Internet-based TV service, the telecommunications giant is replacing 17,000 backup batteries in neighborhoods nationwide after a few exploded or started fires. The batteries were tucked in outdoor cabinets housing equipment for AT&T's U-verse TV service."

The service is offered as an IPTV-broadband bundle (U-Verse) – FTTC broadband is not available as a standalone product. The advertised broadband speed available in top tier bundles is 10 Mbps downstream and up to 1.5 Mbps upstream (AT&T has relatively long residual line lengths compared with the situation in the UK were FTTC to be installed).[193] By the first quarter 2008 AT&T had 379,000 U-Verse TV subscribers, and approximately 9 million living units were passed by the service.[194]

C.4 Uncertainty over business case for fibre investment

We note, in relation to the choice between FTTH and FTTC, that market sentiment in the US has moved towards favouring the Verizon FTTH strategy relative to the AT&T FTTC approach. In part this is due to the comparatively long residual line lengths and therefore limited uplift in performance achieved by AT&T, and in part by the higher than anticipated costs of FTTC.[195]

However, an analysis by Sanford Bernstein questioned the commercial viability of the FiOS investment, taking account of marketing costs and the time required to achieve target market penetration once the fibre service is launched, concluding that costs per connected home would be $3,357 for 50 per cent penetration and that:[196]

"In effect, Verizon is trading an unattractive picture of slow and steady declines in the wireline business for an even more unattractive picture of massive capital reinvestment at below-cost-of-capital returns".

The Wall Street Journal in April 2008 has also reported the widely differing views – a philosophical divide – of investors regarding the demand for faster internet access.[197] The different and changing sentiment regarding fibre investment, and FTTH versus FTTC, highlights the level of uncertainty regarding the correct investment choices.

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[193] http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=25074

[194] http://www.att.com/gen/investor-relations?pid=268

[195] HSBC Global Research. September 2007. "United States of Europe – the Americanisation of European tele-media."

Wall Street Journal. November 2006. "Making calls on Verizon." http://www.shareholderforum.com/vz/Publications/20061102_WSJ.htm

Wall Street Journal. October 2007. "Verizon's FiOS challenges cable's clout." http://www.shareholderforum.com/vz/Publications/20071024_WSJ.htm

[196] Craig Moffett of Sanford Bernstein. January 2008. "Economics of FiOS rollout make little sense for Verizon." Reported in Multichannel. http://www.multichannel.com/article/CA6524100.html

[197] Wall Street Journal. 10 April 2008. "Is faster access to the internet needed?" http://online.wsj.com/article/SB120779422456503907.html

Appendix D: Dynamic considerations

D.1 Discounting and time horizons

Costs and benefits will not all occur at the same point in time, and future costs and benefits are normally "discounted" at some rate to represent them in present value terms. HM-Treasury recommend a real social discount rate of 3.5 per cent for policy appraisal, the Stern review applied a real social rate of time preference of 0.1 per cent,[198] whilst a commercial discount rate appropriate in the communications sector might be at least 10 per cent real.[199]

We only calculate net present values for the lifecycle costs of FTTH and do not attempt to sum up our benefit estimates. In calculating lifecycle costs we assume a life-time of 25 years and use discount rates of 10 per cent.

If there are positive benefits from investing now, then the investment programme that can be implemented i.e. FTTC may gain an advantage in NPV terms over a slower investment in FTTH even if FTTH produced greater benefits per home connected.

D.2 Taking account of the value of the option to wait

An alternative to investing now is to wait – keeping open the option to invest later.[200] The option to invest in future (or never) is left open if investment does not proceed immediately, whereas if investment does proceed much of the cost will be irreversibly sunk (non-recoverable for alternative uses). Where the value of investing is expected to rise over time, or the return on investment is uncertain, this asymmetry in terms of options can create a value to waiting.

New information might include information on costs and demand for FTTH versus FTTC from the US and Europe, and information from the Ebbsfleet FTTH deployment in Autumn 2008. Available and useful data can be expected to expand significantly within the next 18-24 months.

There are also options associated with alternative investments. For example, the option to quickly expand capacity over FTTH by implementing wave division multiplexing (WDM) in future versus the option to move from FTTC to FTTH if demand warrants it. The latter would take time, perhaps almost as much time as a move directly to FTTH without an intermediate FTTC step. By the time demand is clear it may therefore be too late to meet it in a timely manner, and a forward looking judgement is required.

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[198] An approach that has been the subject of critique. See:

Nordhaus. July 2007. "Critical assumptions of the Stern review." *Science*. Volume 317. http://nordhaus.econ.yale.edu/nordhaus_stern_science.pdf

Nordhaus. September 2007. "A review of the Stern Review of the Economics of Climate Change." *Journal of Economic Literature*. Volume 45. Issue 3.

Weitzman. September 2007. "A review of the Stern Review of the Economics of Climate Change." *Journal of Economic Literature*. Volume 45. Issue 3.

[199] Cost of capital estimates for regulatory purposes for BT are in the pretax range 10-11.4 per cent nominal, whilst for mobile they are in the range 12.8-16.4 per cent pretax nominal.

[200] For a discussion of dynamic considerations relating to so called "real options" see Trigeorgis. 1996. "Real options". The MIT Press.

D.3 Certainty with growth

To give an indication of the magnitude of some of the above considerations, consider the case where there is no uncertainty but the value of next generation broadband is anticipated to grow at a rate of 2 per cent per annum – in line with real income growth in the economy. For a 10 per cent discount rate this implies that the value of investment must exceed investment cost by 25 per cent before investment is worthwhile,[201] and that if the value currently equals the cost it would be optimal to wait five years before investing.

D.4 Uncertainty and irreversibility

A hurdle rate is the required rate of return in a discounted cash flow analysis, above which an investment makes sense and below which it does not. The impact of uncertainty on investment hurdle rates with irreversibility and uncertainty is a multiple of the cost of capital and can be calculated under a set of simplifying assumptions (investment is one off and volatility follows a geometric random walk with variance σ^2).[202] In this case uncertainty remains constant over time (commodity prices more or less follow such a process). **Figure D-1** shows calculated hurdle rate multiples (on the vertical axis) as a function of the variance of expected returns for discount rate of 3.5 per cent and 10 per cent.

[201] The formula is V* = r/(r-g) I where r is the discount rate, g is the growth rate, V is value and I is investment cost. From Dixit and Pindyck. 1994. "Investment under uncertainty." Page 138.

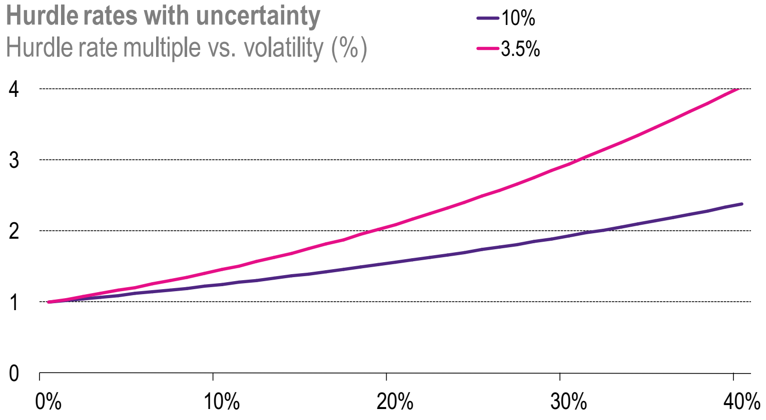
Invest when value > $V^* = \frac{\rho}{\rho - a} I > I$ where ρ is the discount rate, a is the growth rate and I is investment.

The optimal time T* to wait before investing is $T^* = \max\left[\frac{1}{a}\log\left[\frac{pI}{(p-a)V}\right], 0\right]$

[202] Dixit. Winter 1992. "Investment and hysteresis." *Journal of Economic Perspectives*; Volume 6. The formula for the mark-up is:

$p^1 = \frac{\beta}{\beta - 1} p$ where $\beta = \frac{1}{2}\left[1 + \sqrt{1 + \frac{8\rho}{\sigma^2}}\right]$

Figure D-1



Source: Plum Consulting calculations

For a discount rate of 10 per cent and a variance of returns of 30 per cent the real options multiple is 2 i.e. the hurdle rate would be 20 per cent. This gives an indication of the potential magnitude of impact on efficient decisions when real options are considered.

Our expectation is that a considerable amount of uncertainty related to the costs and benefits of next generation broadband will be resolved in the next five years or less, particularly as it relates to the private costs and benefits of next generation broadband.

Appendix E: Costs of FTTC and FTTH

We consider two scenarios – the deployment of FTTH and FTTC to 80 per cent of UK homes and premises.[203] We note that in practice an actual deployment is likely to involve a mix of FTTH and FTTC. We then go on to discuss the implications of a complete replacement of the existing copper network.

The figures used are based on data available from next generation access deployments in other countries (mainly the United States) and should therefore be considered indicative at best. The Broadband Stakeholder Group is currently undertaking further work to develop a specific cost model for the UK (which should be available in Q3 2008).

The OECD reports a range of US$500-$2,500 per household connection for FTTH, and a range of US$100-500 per connection for FTTC. Estimates for the US are summarised in **Table E-1**.

Table E-1: Costs for FTTH and FTTC (US$)

	AT&T[204] FTTC	Verizon FTTH[205]			
	2006	**August 2006**	**Year end goal 2006**	**2008 Sanford Bernstein[206]**	**2010 expected by Verizon**
Cost per home passed	300	873	850	817	700
Cost per home connected	550	933	880	718	650

Note: The Verizon FTTH cost estimates include the cost to pass a home, connect a home, install customer premise equipment, including a wireless router, and ensure the service is working satisfactorily i.e. it is the cost to provision a retail service. They do not include the costs of enhancing other elements of the network to support an enhanced access network.

E.1 FTTC

The estimated cost of FTTC for AT&T in the US is around $850 per home (£425). Other estimates of costs for FTTC include estimates for sub-loop unbundlers from FTTC cabinets in Dublin of around €500 per line (including operating costs),[207] whilst the Broadband Stakeholder Group cited an estimate of €300 (£250).[208]

[203] This is approximately the proportion of UK households located in towns and cities and also roughly corresponds with the footprint of unbundled local telephone exchanges in the UK.

[204] Pers comm. Richard Dineen. January 2008. HSBC. Also provided numbers for Verizon consistent with public figures shown.

[205] With exception of Sanford Berstein column: NetworkWorld. September 2006. "Verizon provides FiOS update." http://www.networkworld.com/news/2006/092706-verizon-fios.html?page=2

[206] Sanford Berstein. January 2008. "Economics of FiOS make little sense for Verizon." http://www.multichannel.com/article/CA6524100.html

[207] ComReg. January 2008. "The business case for sub-loop unbundling in Dublin." http://www.odtr.ie/_fileupload/publications/ComReg0810a.pdf

[208] BSG. "Pipe dreams?" Paragraph 6.26.

FTTC costs in Australia are estimated at around A$4 billion net of any subsidy estimated at up to A$4.7 billion for non-metropolitan areas. For the roughly 7.5 million households in Australia this translates into £535 per household. However, we note that this is the estimated cost for 98 per cent coverage and would therefore be likely to significantly exceed the per household cost for 80 per cent coverage.

Based on US and other estimates we assume FTTC costs, including the costs of service provision (installing and setting up new modems etc) are in the indicative range £250-£400 per household. The total cost of deploying FTTC with 80 per cent coverage would be at least £5.3 billion based on above cost range per household.

We note that, in contrast to FTTH, costs are not very sensitive to service take-up since nearly all the costs are incurred in upgrading the network rather than enabling individual customer service. In contrast, for FTTH the costs of connecting individual households are a substantial part of overall costs.

We note that whilst savings in copper, land and buildings might be achieved with FTTC – operating cost savings are not anticipated and operating costs may increase (particularly if exchange based xDSL service is run in parallel with FTTC).

E.2 FTTH overlaying the copper network

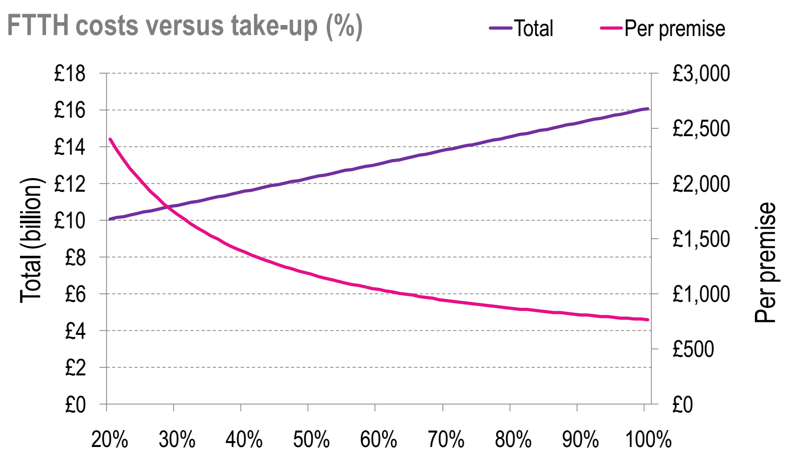
Based on Verizon's costs for FTTH in **Table E-1** above, we assume an up-front capital cost of £410 per home passed and £359 per home connected in 2008, anticipated to fall to an assumed up-front capital cost of £350 per home passed and £325 per home connected by 2010 (assuming an US$:£ exchange rate 2:1). For FTTH costs per customer are highly dependent upon the penetration levels (the percentage of households and businesses that actually take-up the service), as is apparent from **Table E-2** which shows costs for assumed penetration levels of 100, 50 and 20 per cent.

Table E-2: UK indicative cost for FTTH based on Verizon costs (assuming 80 per cent network coverage)

	2008 estimated	2010 estimated
Cost per home passed	£409	£350
Cost per home connected	£359	£325
100% penetration		
Total cost	£16.1 billion	£14.1 billion
Cost per home connected	£768	£675
50% penetration		
Total cost	£12.3 billion	£10.4 billion
Cost per home connected	£1,176	£1,025
20% penetration		
Total cost	£10.1 billion	£8.7 billion
Cost per home connected	£2,402	£2,075

Figure E-1 illustrates the sensitivity of FTTH total and per premise cost to take-up.

Figure E-1



Source: Plum Consulting calculations

E.3 FTTH with replacement of copper

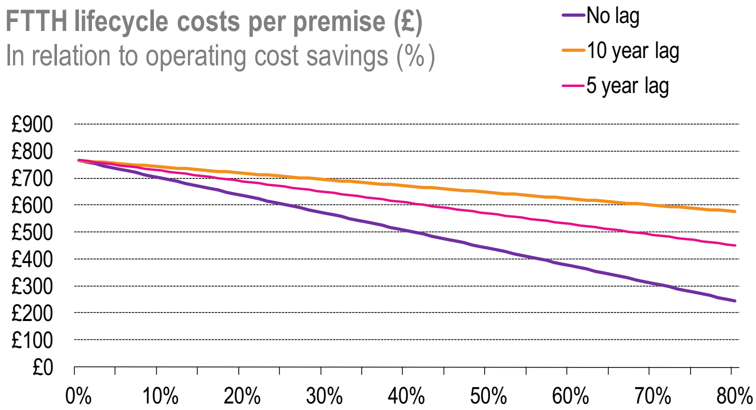
As an alternative to FTTH overlay, FTTH could be deployed as a replacement for the copper telephony broadband network with the explicit aim of 100 per cent connection of premises to fibre and copper network shutdown location by location as fibre is rolled out (100 per cent connection is required to maintain service with copper network shutdown). Whilst additional costs would be incurred in migrating services over to fibre, the need to operate one rather than two networks would result in significant operating cost savings over time. The existing copper network could be sold as a going concern, or for the scrap value of copper (which puts a lower bound on its value).

Given uncertainty over the level of operating cost savings that might be achieved, we have calculated savings assuming that operating costs for an all fibre network with 80 per cent coverage can be reduced anywhere in the range 0 to 80 per cent. We also consider the possibility of achieving operating costs savings almost immediately, or with delays of 5 or 10 years.

We base our indicative cost estimate on the cost to pass and connect a home utilising the US estimate of £768 per home, or £16.1 billion in total for 80 per cent coverage and a 100 per cent connection rate. There may be capital cost economies for a replacement FTTH programme due to scale economies and the opportunity to lay fibre and connect homes at the same time, which we have not factored in. Our estimate for base level operating costs is those for Openreach for SMP services excluding depreciation – an estimate of £1,862 million in total or £71 per premise per annum.[209] We note that operating costs for the 80 per cent coverage area of FTTH deployed could be expected to be lower than average – we have not allowed for this.

Utilising the above assumptions, **Figure E-2** shows calculated lifecycle costs for FTTH with different levels of assumed operating cost saving (on the horizontal axis) and lags in achieving savings of 0, 5 and 10 years – all calculated for a 10 per cent real discount rate over 25 years.[210]

Figure E-2



Source: Plum Consulting calculations

It is clear from the figure that if substantial operating cost savings could be achieved quickly the lifecycle costs of FTTH with copper replacement might be substantially reduced. The calculations also indicate, if this option stands up to further analysis, that achieving rapid copper replacement area by area as fibre is deployed is crucial to achieving large reductions in lifecycle costs.

[209] The operating costs excluding bad debts, other costs and depreciation for Openreach – the access network – are £2,648 million per annum, of which £1,862 million per annum relates to residential and business full service provision markets (excluding non-SMP Openreach services). These costs include an amalgam of costs – some of which may offer scope for cost reduction with fibre whilst others may not.

BT. "Current Cost Financial Statements for 2007 including Openreach Undertakings." Page 113. http://www.btplc.com/Thegroup/Regulatoryinformation/Financialstatements/2007/CurrentCostFinancialStatements.pdf

[210] If the social HM-Treasury discount rate is utilised, operating cost savings alone above around 60 per cent over 25 years would bring the life-cycle social cost down to zero (before consideration of any other potential benefits). We note that Crossrail was evaluated utilising a 3.5 per cent discount rate and a 60 year time horizon.

In terms of feasible operating cost reductions discussions with industry and estimates for operating cost savings in relation to fibre deployment by Verizon in the US (discussed in Appendix C – with an estimate of savings of around £55 per line per annum or around 70 per cent of our assumed UK cost base). We conclude that operating cost reductions could be substantial for a fibre only network versus running a legacy copper network alongside fibre. However it would not be costless to achieve such savings with both telecoms and non-telecoms systems (traffic lights for example) needing to be migrated. We have not estimated such costs.

Given the uncertainty over operating cost savings and the fact that we do not account for the cost of achieving such savings, we consider assumed savings in the range 30 to 50 per cent with a minimal lag in achieving savings. Under these assumptions the cost of an FTTH replacement might fall from £768 per household to £572 respectively, or a total cost of £12 billion to £9.3 billion for 80 per cent coverage and 100 per cent take up. However, overall savings, including proceeds from the sale of copper and land and buildings, could potentially be greater than the above assumptions and net lifecycle costs correspondingly lower.

There are also potential savings including avoided future capital expenditure on the copper network, and gains from the sale of copper and land and buildings. Below we provide estimates of the latter two.

We estimate the value of copper based on the length and gauge of wire in the UK. There are 120 million kilometres of 0.5 mm diameter copper in BT's network.[211] Recovery of 100 per cent of this copper would yield 220,000 tonnes of copper at a price of £8,335 per tonne in April 2008, a value of around £900 million. For 80 per cent network coverage the value is £0.7 billion. In practice there would be costs associated with recovering the copper and recovery may be partial.

In relation to land and buildings, an HSBC note suggests that BT can sell some of its local exchanges, provided it shares the benefits with Telereal, its sale and leaseback partner, and concludes that *"We think BT could raise a couple of hundred million pounds by this route, offsetting perhaps 10% of an ambitious FTTN/VDSL build."*[212] Whilst this element is appropriable, there may be additional non-appropriable value associated with freeing up land and buildings where there are alternative higher value uses.

Together the value of copper, land and buildings might realise up to £1 billion during the investment phase, which could be netted off the investment cost. We do not treat this as an additional saving; rather we treat such gains within the cost savings assumptions in relation to copper replacement.

[211] Openreach. http://www.openreach.co.uk/orpg/aboutus/Downloads/web_corp_brochure.pdf

[212] HSBC. 5 December 2007. Company report on BT Group. Page 61.