Understanding the Environmental Impact of Communication Systems

Final Report

27 April 2009

Colin Forster
Ian Dickie
Graham Maile
Howard Smith
Malcolm Crisp

Document Name GGR007

Version 03

Distribution:
Gary Clemo Ofcom
Graham Maile Plextek
Colin Forster Plextek
Ece Ozdemiroglu Eftec
Ian Dickie Eftec
## Revision History

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<td>30 Jan 09</td>
<td>First Version</td>
<td>CHF, ID, GLM, HJS, MC</td>
<td>GLM</td>
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<tr>
<td>02</td>
<td>27 Mar 09</td>
<td>Revision</td>
<td>CHF, ID, GLM</td>
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<td>03</td>
<td>27 Apr 09</td>
<td>Revision</td>
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Version 03 Approved by GLM
Executive Summary

Study context

This study formed part of Ofcom’s 2008/2009 technology research programme. Its purpose was to assist Ofcom to better understand the type and degree of environmental impact that communication systems can have and to assist thinking on the ways Ofcom might wish to take more account of environmental impacts as part of its duties. Some of Ofcom’s current duties have environmental aspects associated with them but these are very limited indeed.

The work had three main aims. The first was to provide a reference point for Ofcom in terms of relevant environmental background material, data examples, analyses, and key source references. The second aim was to help understanding of the scale and type of impacts communication systems can have. And the third aim was to consider where Ofcom might take greater account of environmental impacts in future decision-making, policy development or spectrum licensing, where impacts are not already being addressed by other routes. The study was not intended to be a definitive impact assessment of UK communication systems, but was intended to inform on a range of relevant issues and provide insight into environmental impacts for communication systems relevant to the UK.

The scope included both wired and wireless systems, and the methodology comprised a combination of detailed literature surveys, discussion with selected communications experts and organisations, analysis of environmental evaluation process issues, and development of specific case studies. Consistent with the exploratory nature of the study, discussion with selected organisations was conducted on a sampling basis and did not constitute a formal consultation activity on behalf of Ofcom.

The study was conducted in the context of UK environmental impacts and greenhouse gas emission reduction targets. Forecast UK emissions are of the order of 621 MtCO₂e (megatonnes carbon dioxide equivalent) in 2010\(^1\) for all sectors (Figure 1), approximately 20% below the level for base year 1990. UK commitments are for further reductions of 26% by 2020, and 60-80% by 2050.

![Figure 1. UK Greenhouse Gas Emissions by end-user (2010)](source: UK Climate Change Programme, HM Government, 2006)

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\(^1\) Original forecast from the UK Climate Change Programme 2006: this figure was revised in the July 2008 Annual Report to Parliament taking account of allowances under the EU Emissions Trading Scheme (ETS), but still yields of the order of 600 MtCO₂e for 2010.
Impacts of systems

Amongst the many types of environmental impacts that can be identified, the major environmental impact for communications systems is Climate Change, so carbon emissions related to energy consumption are the first environmental management priority. Dominant contributors are operational (use-phase) energy, and embodied carbon from manufacturing. Following these, electronic waste, use and toxicity of materials and, for infrastructure, visual and landscape use impacts are key environmental issues.

Depending on the type and complexity of the system, impacts can be significant. Key determinants are the quantities of physical sub-systems and products used, and the energy efficiency of the most energy-consuming sub-systems. Other important factors are the rates of replacement, product lifetimes and transition periods as systems are enhanced or superseded.

In terms of the data available in the literature, the study shows that much work has been and is being done to assess the impact of ICT systems as a whole and on a global basis, but data relating specifically to communication systems is more limited.

There is basic agreement on the broad ICT picture, with the total global carbon footprint currently being of the order of 800 MtCO$_2$e or approximately 2% of global emissions. This is predicted to grow to around 1,400 MtCO$_2$e by 2020, or approximately 2.8% of global emissions at that date.

Of this, contributions from global telecommunication systems - mobile, fixed and communications devices but excluding TVs & TV peripherals - currently approach 29% or approximately 230 MtCO$_2$e. TVs and related peripherals contribute of the order of 700 MtCO$_2$e, nearly as much again as the total for global ICT.

Consumer equipment, where devices have small individual impacts, often have very substantial impacts overall due to the large volumes involved and shorter product life compared to infrastructure systems - so impacts from manufacturing and disposal become at least as significant as energy consumption.

Case studies

To gain more specific insight, the case studies explored the major impacts of selected communication systems. The 2G/3G case study considered the environmental impacts of mobile networks representative of current UK networks. It is evident that the carbon footprint of cellular mobile networks is substantial within telecommunications, with the dominating contributors being network use-phase energy consumption and embodied carbon in handsets. Handsets have a relatively low use-phase impact in terms of energy consumption, but have a substantial impact when overall life cycle impacts are considered (manufacture, distribution, disposal/recycling) as a result of their short product life, typically 1-2 years for a significant proportion of handsets in the UK.

It is concluded that whilst the energy consumption of 3G base stations can be at least as good as 2G base stations (for an equivalent number of voice circuits and operating at the same carrier frequency), the growth in 3G broadband mobile data services is a significant environmental issue. Subscriber-pull for the full range of 3G high data-rate services will create pressure to deploy more network resource.

The digital terrestrial TV (DTT) case study looked at the main impacts of both the transmission system and of consumer equipment, concluding that for the network, the operating (use phase) energy consumption is the dominant impact. The long service life of network equipment results in low annual contributions from embodied carbon (manufacturing and installation) and from recycling, as these are averaged over the expected life of the system (10-20 years upward).
The DTT network will ultimately provide an environmental advantage compared to analogue, but not while both networks are still operational. DTT transmission network power consumption is significantly overshadowed by the use-phase energy consumption of domestic TV sets and of other receiving equipment, these being of the order of 50 to 100 times greater than the total network consumption.

A theoretical scenario of satellite broadcasting fully replacing DTT at some point in the future was also considered and concluded that the environmental benefits would be relatively modest, given that consumer equipment is the dominant contributor compared to the DTT network, and that there would be additional impacts as part of replacing consumer equipment and installing new domestic antennas.

The introduction of digital TV provides a good example of the generic issue of spectrum usage. DTT brings benefits compared to the previous analogue transmission system, as a result of advances in technology such as efficient modulation schemes and advanced compression techniques. The result is more channels transmitted in significantly less spectrum, with less network energy consumption compared to analogue. Paradoxically, however, this makes it possible to operate more systems in the same amount of spectrum and, thereby, potentially increasing environmental impacts in the future.

The femtocell case study considered the deployment of femtocells in the home to provide indoor 3G coverage. It is concluded that femtocells could have a considerable operational energy advantage over the hypothetical alternative of expanding the macrocell network to provide approximately similar indoor coverage.

A range of activities were also identified in the study which are addressing environmental issues surrounding fixed broadband and FTTx networks, including work by the FTTH Council and the ITU. Primary FTTx impacts are: use-phase energy consumption of the fixed network and of consumer equipment; manufacturing and deployment impacts of new infrastructure and consumer products; and most significantly, the impacts of civil installation works required to deploy fibre at regional and national levels.

Based on our analysis, the large communication systems studied in detail in this report are making a relatively small but noticeable contribution to total UK CO₂ emissions (Table 1).

<table>
<thead>
<tr>
<th>Communication system</th>
<th>Approximate energy consumption GWh/year</th>
<th>Approximate emissions MtCO₂e/year</th>
<th>As % of total UK emissions</th>
<th>As % of total UK domestic emissions</th>
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<tr>
<td>3G transmission networks</td>
<td>300</td>
<td>0.18</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>2G transmission networks</td>
<td>1000</td>
<td>0.60</td>
<td>0.10</td>
<td></td>
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<tr>
<td>DTT full transmission network (2012)</td>
<td>114</td>
<td>0.07</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Domestic TV equipment</td>
<td>5900</td>
<td>3.54</td>
<td>0.57</td>
<td>2.5</td>
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Table 1. Examples of communication system greenhouse gas emissions contrasted with UK total 2010 emissions

As noted, consumer TVs and related equipment are particularly significant, being widely deployed consumer products with daily usage. The EU and Defra initiatives to target consumer equipment energy and standby consumption are thus well justified, but the active (on mode) power consumption of the TV set remains a priority, as it contributes the most to total daily set consumption – typically around 80%.
Transition strategies strongly influence environmental impacts

The evolution of physical systems over time, and particularly the transitions between older and newer generations of communication systems, has a very important influence on environmental impacts. New systems are often implemented to provide new or enhanced services and geographic coverage, whilst supporting broadly similar core services to existing ones.

This transition can last a shorter period, if an explicit migration strategy is adopted, or for very many years (decades) if market demand, commercial viability or other factors sustain the demand for both older and new systems and services.

The former case is typified by the strategy followed by the UK and many other countries for the transition to digital terrestrial TV and the switch off of analogue transmissions. The clear timetables set out, whilst extending over a number of years, nonetheless will result in an overall reduction in the impact of the transmission networks once analogue is switched off.

By contrast, and compared to the change from the previous generation of analogue ‘1G’ cellular (where a final switchover date was set), the 2G-3G ‘migration’ is effectively market-driven, based on commercial and service considerations by the operators. Thus whilst 3G opens the way to significantly enhanced services over basic voice, there is a level of service duplication which is less than optimal from a purely environmental perspective.

Environmentally, the introduction of new generation systems and the migration from legacy systems should be planned where possible so as to minimise the extent to which ‘duplicate’ physical systems and products co-exist, whilst meeting commercial, regulatory and public benefit requirements. In this context it was concluded that the development of better tools to analyse and identify optimum transition strategies for given cases would be beneficial, which would take account not just of technical and environmental system aspects, but also requirements such as continuity of service requirements, return on investment issues for operators, equivalence of coverage, and the desirability of maximising consumer product lifetimes.

Positive impacts of communication systems

As well as their direct negative impacts, communication systems have significant potential to provide positive environmental benefits, especially with respect to reducing the emissions that result from travel. However these benefits are not an inevitable consequence of greater uptake of systems and services. Rather, communications systems and services are critical enabling elements, essential to implementing wider initiatives and policy changes that in practice are the actual drivers of actions and changes in behaviours. It is these that (may) then lead to reductions in environmental impacts in other areas.

Quantifying these positive impacts is complex compared to evaluating direct negative impacts, and relies on many more assumptions as to the likely take up and the effectiveness of applications and services. A number of current studies of communications and ICT impacts take an optimistic view of the positive benefits that ICT can provide, without taking due account of other regulatory, policy and behavioural changes necessary to achieve the expected benefits. Communications services can be effective in offsetting travel and emissions in other sectors, but they must be supported by other actions, such as setting appropriate policy and implementation objectives and developing users’ skills.

The challenge of communication services growth

Considering the nature of communication systems and services as a whole, a fundamental balance must be continually struck between, on the one hand, the increasing environmental impacts as systems and services grow, as technology and markets develop and as more hardware and products are deployed, and on the other hand, the benefits delivered by such systems and services (Figure 2).
Benefits include social and economic benefits as well as commercial ones - communication systems are an increasingly essential element for the functioning and growth of the UK economy, providing desirable services to citizens, consumers, business and Government. This tension is considered to be a key challenge for the communications industry going forward.

**Figure 2. Factors affecting the environmental impacts of communication systems**

Practically, it is useful to consider that all communication systems have some associated environmental ‘costs’, which must be accepted in order to obtain the benefits the systems provide. Environmental consideration then dictates that wherever possible these costs (impacts) be minimised and reduced over the full life of each system. This is especially important when multiple, duplicated, systems provide similar services. If needed, mechanisms (licensing, regulation, standardisation) can then help promote environmentally responsible implementation and action by industry.

In this context, assessing *absolute* impacts is more useful than trying to compare relative environmental impacts of systems and products. If the absolute impacts of a system are determined to be substantial, actions to minimise and continually reduce them are worthwhile - even if the impacts can only be determined to a given accuracy. If absolute impacts are small, then there is a lesser environmental priority to address them. Minimising the absolute impacts of all systems is the key issue for Climate Change.
Implications for Ofcom

The introduction of new communication systems and major developments in existing ones can require the involvement of various groups from both Government and industry. Factors affecting environmental impacts may be influenced by a range of bodies, depending on whether they relate to technical aspects of the system, commercial considerations, or Governmental/national decisions regarding service levels, competition and coverage.

A simple illustration for the case of DTT is shown in Figure 3. (Note that original DTT planning involved previous bodies such as the DTI, ITC and others). UK DTT is based on original DVB (now ETSI) standards, but with specific UK technical details decided by the UK DTG group. The Government defined implementation and analogue switch-off decisions, with Ofcom responsible for spectrum allocation and licensing. Original DTT impact evaluations were conducted by DCMS as input to Government decisions, whilst energy consumption of products is (now) addressed by Defra and by operators and manufacturers implementing Defra and EU directives and guidelines.

This collaborative approach is true for many other systems, so that only specific areas fall within Ofcom’s remit to potentially consider environmental issues - primarily spectrum planning and licensing and system requirements to adopt ‘greener’ technical standards.

In terms of ‘what might have been done differently’ when DTT was originally planned (or if it were being considered today), a decision for a faster switchover from analogue could have reduced the impacts of parallel network operation, and allowed a more optimised ‘green’ replacement strategy of consumer equipment. Introduction of power consumption limits and reduction targets directly into UK receiver specifications would also have been beneficial.

More radically, a detailed evaluation of digital television via satellite might have been conducted at the outset, compared to implementing a new terrestrial network. Ofcom might have considered this from both a coverage perspective and from the potentially greater transitional issues, particularly regarding the need for a satellite dish on all dwellings, and dealing with satellite blind spots in urban areas. The DTT case study concludes this approach could have reduced landscape impacts and network energy consumption, but with the possible downside of higher active energy consumption (and cost) for consumer receivers, at least in the earlier years.

For 2G and 3G mobile cellular, a formal transition strategy was never defined and there was no assumption that 3G would necessarily replace 2G, given there were complex issues which included...
national UK coverage requirements, the challenges of 3G system and handset technology development, and returns on investments for 2G operators.

As an example of alternative decisions that might have been considered, earlier introduction of requirements to restrict handset subsidies by operators could have created a more independent handset market, and encouraged users to keep their mobile phones for longer before upgrading.

On the network side, a single 3G physical network, licensed to an infrastructure service provider offering shared network access to competing 3G operators, could have offered a more optimised network in terms of environmental impacts, whilst meeting total coverage and capacity requirements. Alternatively, passive or active network sharing might have been mandated.

In this context, current industry activity to find ways to improve sharing of existing base station sites and of equipment is encouraging, and the announcement by French regulator ARCEP calling for a sharing framework to be developed by French mobile operators, is a specific example of regulatory intervention to gain environmental (and other) benefits.

With regard to the 3G spectrum auctions that took place in year 2000, it is possible to envisage how incentives might also have been explored to encourage improvement over time of the environmental footprint of systems. An example is the use of staged/tiered payment structures (with financial bonuses or penalties), implemented against agreed environmental criteria and performance improvements over time.

Looking forward, Ofcom could explore favourable licensing arrangements for communication services and applications that have potentially positive environmental benefits - for example smart metering and travel information/automation systems. These arrangements might include discounted or deferred payment mechanisms for successful implementation of services. Where application specific licence-exempt spectrum is more appropriate (e.g. for monitoring and control of building energy use), a small amount of dedicated spectrum might be allocated on a national basis to actively encourage the development of ‘environmentally-related’ applications.

The study work has confirmed the importance of the lower frequency bands from an environmental perspective, especially in the context of rural and indoor coverage. Also, whilst not studied here, the assignment of wider band spectrum blocks and novel spreading / multiple access arrangements enabling reduced energy consumption deserves further investigation.

**Current activities**

Much cross-sector activity is underway to address environmental issues, including the EU Energy using Products (EuP) programme and directives, Defra’s Market Transformation Programme (MTP), and the activities by the ITU and ETSI. At the same time, manufacturers and operators are increasingly working toward reducing the environmental impacts of their own businesses and products, as part of reducing operational and energy costs (a ‘win-win’ situation in many instances), reducing their materials use and recycling costs, and as part of commercial competition to promote ‘greener’ positioning in the market.

Good progress is already happening, and regulatory intervention (as compared to coordination) is in many cases likely to be unnecessary or counterproductive. However there appears a lack of clear direction or guidance specific to the communications industry, a sentiment also expressed by a number of industry representatives interviewed. In particular, Ofcom could consider (as communications regulator) coordinating and/or leading work on common baselines for environmental analysis, and identifying environmental priorities and the emphasis that these will be given in future.
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1 Introduction

This study formed part of Ofcom’s 2008/2009 technology research programme. Its purpose was to assist Ofcom to better understand the type and degree of environmental impact that communication systems can have and to assist thinking on the ways Ofcom might wish to take more account of environmental impacts as part of its duties.

The work formed part of Ofcom's long-term research work, and was conducted between May 2008 and March 2009.

1.1 Objectives & scope

Some of Ofcom’s current duties have environmental aspects associated with them but these are very limited indeed, relating to the Communications Code and Ofcom’s duties regarding advertising and claims about environmental impacts.

The work thus had three main aims. The first was to provide a reference point for Ofcom in terms of relevant environmental background material, data examples, analyses, and key source references. The second aim was to help understanding of the scale and type of impacts communication systems can have. And the third aim was to consider where Ofcom might take greater account of environmental impacts in future decision-making, policy development or spectrum licensing, where impacts are not already being addressed by other routes.

The study was not intended to be a definitive impact assessment of UK communication systems, but to inform on a range of relevant issues and provide insight into environmental impacts for communication systems relevant to the UK. The scope included both wired and wireless systems.

The study was conducted in the context of UK environmental impacts and greenhouse gas emission reduction targets. Forecast UK emissions are of the order of 621 MtCO$_2$e (megatonnes carbon dioxide equivalent) in 2010$^2$ for all sectors (Figure 1), approximately 20% below the level for base year 1990. UK commitments are for further reductions of 26% by 2020, and 60-80% by 2050.

![Figure 1.1. UK greenhouse gas emissions by end-user (2010)](Source: UK Climate Change Programme, HM Government, 2006)

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$^2$ Original forecast from the UK Climate Change Programme 2006: this figure was revised in the July 2008 Annual Report to Parliament taking account of allowances under the EU Emissions Trading Scheme (ETS), but still yields of the order of 600 MtCO$_2$e for 2010.
1.2 Context

Communication systems may have associated increases or decreases in positive or negative environmental impacts, with a very broad range of environmental impacts to consider and prioritise between. As defined in this report, environmental impacts of communication systems can be 1st order (e.g. a system’s energy consumption), 2nd order (e.g. smart metering enabling better management of buildings’ energy consumption), or 3rd order (e.g. teleconferencing enabling reduced need for travel).

Ofcom might, potentially, have most influence over certain 1st order impacts, but in practice the decisions it makes may have the greatest impact on environmental outcomes by helping to influence behaviours (like travel patterns or hardware turnover rates) that involve communications technologies.

In addressing these impacts, Ofcom could initiate its own proactive approach to regulating environmental issues, or seek to align its activities with existing approaches, for example, existing waste-management strategies in Government or industry best practices. The work of this study is therefore to assist understanding and input to thinking on the possible benefits and disadvantages of different approaches.

1.3 Methodology

The methodology for the study comprised:

- Secondary research - survey and analysis of existing work and studies in the field
- Discussion with selected academic and environmental experts
- Discussion with selected organisations in the communication sector (operators, manufacturers, service providers and industry bodies)
- Development of a number of case studies to illustrate the type of thinking that may be applied to evaluate aspects of communication system impacts
- Analysis of process issues in undertaking environmental evaluation
- Analysis of potential implications for Ofcom.

Consistent with the exploratory nature of the study, discussion with selected organisations was conducted on a sampling basis and did not constitute a formal consultation activity on behalf of Ofcom.

1.4 Report structure

The report is structured as follows.

Section 2 introduces background environmental information and terminology to assist better understanding of the rest of the report, with Appendix A providing more in-depth detail of environmental terms and methods, and Appendix H providing background on landscape impacts.

Section 3 introduces the literature research undertaken during the project and highlights the overall impact of communications systems. It also guides the reader to the detailed literature review findings in Appendix B and the data examples in Appendix C: together these provide a review of key work and sources specific to communication systems.

Section 4 discusses the approach to environmental evaluation in the context of communication systems, and the need to take a hierarchical, systems and services approach to analysis.
Section 5 presents example analyses in the form of case studies, these being: the relative environmental impact of providing 3G coverage in the home via femtocells vs. extending the macro base station network; the impacts of 2G/3G mobile networks; and the impacts of digital terrestrial and satellite TV.

The aim of the case studies is not to provide definitive evaluations of current UK systems, but rather to develop in more detail the type of thinking and the range of issues and assumptions involved when considering environmental impacts of communication systems. However they do give example data and conclusions relevant to UK systems.

While the case studies focus on direct (negative) environmental impacts, Section 6 discusses the positive effects that can be associated with communication systems.

Conclusions and recommendations are presented in Section 7.

The development of an overall environmental approach and framework is discussed in Appendix E, on the basis of if Ofcom was required to address environmental aspects of systems. Economic methods useful in supporting environmental assessments are detailed in Appendix F.

Appendix G draws together and summarises some key process issues which were identified during the study, that arise when seeking to evaluate system impacts.
2 Environment background

This section presents a short introduction to key terminology, definitions and approaches adopted in the assessment of environmental impacts, providing necessary background to discussions in the subsequent sections. More in-depth information of the issues and techniques outlined here may be found in Appendix A.

2.1 Background and terminology

Defining and measuring environmental impacts is complex, and can occur at a number of levels and scales. Different approaches for assessing environmental impacts can be appropriate for different sectors or within different decision-making contexts. Environmental impacts are commonly assessed in categories, and the full range of categories used in life cycle assessment (see below), is described in Appendix A. Key categories for the communications industry are identified in Appendix E as part of the consideration of a possible Ofcom environmental framework.

The majority of environmental impacts can be quantified as materials flows, and while these may not be easy to measure, they are relatively straightforward to define. Impacts on landscape and biodiversity can be more qualitative, and therefore require careful definition. Of these, landscape impacts are more relevant to Ofcom’s activities, and are considered in more detail in Appendix H.

2.1.1 Types of environmental impact

Frequently in environmental analysis, such as in defining the scope of organisations to influence carbon emissions, reference is made to the concept of direct and indirect impacts. This terminology can have multiple meanings and there is a lack of consistency of definitions between studies of communications systems. In this report we have adopted the definition of three orders of effects used in academic research (e.g. Hilty et al, 2006):

- **First order**: effects from physical existence of ICT.
- **Second order**: effects due to the power of ICT to change processes (e.g. transport), resulting in changes in environmental impacts related to those processes.
- **Third order**: effects arising due to collective medium or longer-term adaptation of behaviour (e.g. consumption patterns) or economic structures.

First-order impacts from communications systems are usually negative - arising directly from the manufacturing, assembly, installation, operation and disposal of a system, etc. The second and third order categories cover ‘indirect’ effects, which arise from the influence a communication system may have on other applications, processes or behaviours. They can be positive or negative, and can depend on complex sociological interactions. The term ‘rebound effects’ is also sometimes used to refer to new activities (and therefore additional environmental impacts) arising as a result of 3rd order behavioural influences.

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2.1.2 Climate Change policy

There is now a global scientific consensus that unless human emissions of carbon⁴ are significantly reduced, dangerous climate change will result. The UK’s Climate Change Act commits it to ongoing emissions reductions. These reductions are contingent on the result of negotiations on post-Kyoto global emissions targets that will take place in Copenhagen in December 2009. The UK is committed to emissions reduction targets in its interim carbon budget (60% cut by 2050), and with an adequate global agreement will extend these to its intended budget (which recognises the developing science suggesting an 80% reduction may be required).

The UK Government’s approach to climate change policy is one of global leadership. As the UK’s own emissions are relatively small in global terms, Government action to cut emissions is motivated not only by the need to contribute to international emissions reduction efforts, but also to provide a strong standpoint from which to argue for collective global action.

The UK’s Climate Change Act also requires Government to issue guidance in 2009 on the way companies should report their greenhouse gas emissions. In addition, by April 2012, it must use powers under the Companies Act to mandate carbon reporting, or explain to Parliament why it has not done so.

2.1.3 Climate Change terminology

The focus on Climate Change as the most pressing current environmental issue has led to a range of practices and approaches for reporting and analysing carbon emissions. Climate Change concepts, such as ‘carbon footprints’ and ‘carbon neutrality’ are becoming widely recognised in both business and society as a whole.

When organisations report their greenhouse gas emissions, they typically distinguish between the degrees of control they have over the sources of emissions. This is because although emissions may arise as a direct result of the organisation’s activities (e.g. through a supplier), the organisation may not have control over the level of emissions (e.g. the supplier’s choice of transport). This leads to emissions which an organisation has different levels of influence over, described as Scope I, II, and III.

The Scope of emissions is distinct from the classification of 1st, 2nd and 3rd order impacts introduced in 2.1.1. It should also be noted that both Scope and 1st/2nd/3rd order classifications relate to the type of impact, not the severity.

When thinking about the broader life cycle of a product’s carbon impacts, consideration should also be given to the carbon ‘embodied’ or ‘embedded’ in a product. These are the emissions that have gone into manufacturing and supplying a product to the point of use, and are particularly relevant to UK imports, such as communications hardware (see Geographic Boundary Issues below).

CO₂ emissions are related to energy consumed by products and systems via ‘emission factors’, which depend on the source of the energy (electricity, oil, gas, biofuels, renewables, etc) and the method used to extract it. For ICT and communication systems, grid electricity is typically the form of energy used, although local power generation is also relevant in certain cases (e.g. instead of using grid electricity, mobile base stations may have oil-fed generators, or use solar or wind power generation, and the resulting levels of CO₂ emitted will be different).

The Climate Change Act (2008) contains a clause on making carbon-reporting mandatory for certain sections of the economy (e.g. firms over a certain size), subject to Government review in

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⁴ The term ‘carbon’ is used here to reflect the different forms in which carbon can occur as (e.g. oil, coal, and gases like CO₂ and Methane (CH₄)), and is viewed as analogous to all sources of Greenhouse Gases. The Climate Change impact of emissions of carbon is measured as CO₂ equivalents (CO₂e).
2010. This commitment has stimulated ongoing work in Government on the standardisation of carbon accounting practices, drawing on existing carbon reporting processes (e.g. the Greenhouse Gas Protocol\(^5\) initiative).

### 2.1.4 Sustainability

Recent alterations to regulators’ duties (see Section 7.3) have made reference to Sustainable Development (SD). Most current definitions of Sustainable Development originate from the Brundtland Report\(^6\), which identified the requirement to meet our own needs without compromising the ability of future generations to meet their needs. The current UK SD Strategy (‘Securing the Future’ HM Government, 2005\(^7\)) defines SD through its stated aim:

“...to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life without compromising the quality of life of future generations.”

Environmental issues feature strongly, including the concept of environmental limits. The World Business Council for Sustainable Development (WBCSD) has developed the concept of eco-efficiency - delivering the goods and services that satisfy human needs while progressively reducing ecological impacts and resource intensity throughout the life cycle.

### 2.2 Environmental analysis approaches

There are many approaches and tools available for undertaking the analysis of environmental impacts. Two assessment methods that are required in certain circumstances by EU Law are Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). These involve detailed analysis of different types of positive and negative environmental impacts of the issue being assessed – either at the project/development level (EIA), or the plan or programme level (SEA).

Life cycle assessment (LCA) is a tool for estimating the total environmental impact of a given product or service throughout its lifespan, from cradle to grave\(^8\). The term 'life cycle' reflects the assessment of raw material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence. LCA can guide ICT devices and applications towards having net positive environmental effects, allowing in-depth analysis\(^9\). However, accurate LCA is complex and time consuming, and heavily dependent on assumptions.

The concepts of carbon intensity and material intensity relate an environmental impact (material use or carbon emissions) to measures of ‘benefits’. For example, carbon intensity gives the amount of carbon generated for a given system performance measure (e.g. speed, network traffic). Sometimes environmental evaluations can be made in monetary terms using economic appraisal methods, but in other cases monetary values for environmental impacts cannot be agreed on, and alternative approaches (such as cost-effectiveness analysis) may be employed. More detailed

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\(^6\) [http://www.un-documents.net/wced-ocf.htm](http://www.un-documents.net/wced-ocf.htm)


discussion of this and economic-specific tools is given in Appendix F.

2.3 Geographic boundary issues

A key issue that arises in discussing the sustainability of any economic system is the boundary of the system. The UK is a highly developed economy, with a large proportion of economic activity in the service sector, and substantial overseas sourcing of both raw materials and finished industrial products. In other words, the UK imports a lot of the goods it needs, and these goods have significant embodied carbon, materials and other environmental costs. Thus a UK-only analysis will give a partial picture of the total environmental impacts of UK production and consumption.

The importance of the overseas environmental impacts of UK activities, and putting these in the context of the UK’s total global (domestic and overseas) impacts, is complex and controversial. It is not straightforward in any sector, including in relation to the communications industry. However, knowledge of the life cycles of communications systems highlights that there are major impacts at the material extraction and manufacturing stages (through global supply chains, and in particular in the Far East), and disposal stages (in particular in developing countries such as West Africa, India and China\textsuperscript{10}).

3 Industry studies

In order to identify existing studies, activities and results relevant to understanding the environmental impacts of communication systems, a detailed literature survey and supporting research was conducted.

3.1 Literature survey & data examples

In the past 3-5 years environmental issues have become an active field both for both academic research and for studies by a range of environmental & government groups and commercial organisations. Environmental and government groups have been focusing on products and systems that have the most significant impacts, whilst many commercial organisations have developed understanding of and action plans for reducing the environmental impacts of their internal operations and activities as part of wider corporate social responsibility (CSR) initiatives.

In particular, much work has been done to assess the impact of ICT systems as a whole, although there appears to be limited data relating to the overall UK communications industry. There is some degree of consistency in the results, but it becomes readily apparent that significant care is needed when interpreting the results, given the differing assumptions, scope of analyses and geographical variations (for energy conversion to CO2e, for example).

Please refer to Appendix B for a detailed listing and summary comments on current leading studies that were identified and evaluated. Of particular relevance are the reports by the Smart 2020 report (‘Enabling the low carbon economy in the information age’) by The Climate Group/GeSI, which assessed the (global) carbon footprint for ICT and major communications systems, and the Ericsson (Malmodin) study (‘Carbon footprint of mobile communications and ICT’), which included consideration of entertainment and media (including TV sets and related devices). Further analysis was performed on the data in the Smart 2020 report in order to provide a consolidated view of the broader impacts - see Table 3.1 and Figures C.1 and C.2 in Appendix C.

Overall there is basic agreement regarding the direct global impacts of ICT and communication systems, with the total global carbon footprint of ICT systems being currently of the order of 800 MtCO2e, accounting for approximately 2% of global emissions. This is estimated to grow to around 1,400 MtCO2e by 2020, or approximately 2.8% of global emissions at that date.

Of this, global telecommunication systems (mobile, fixed and communication devices) currently contribute approach 29% (of the order of 230 MtCO2e) - but this excludes the significant impacts from consumer entertainment and media, of which TVs, related media devices, printers and copiers, are the dominant contributors.

The Ericsson study data (Table 3.2) provides estimates for TVs and related media devices, which together contributed of the order of 500 MtCO2 (for both use phase and whole life cycle impacts) in the baseline year of 2005, around twice that of the whole telecommunications sub-sector (taken to include some data centre contributions).

Based on these studies and growth estimates, we estimate TV and related equipment to have a current impact of the order of 700MtCO2e. Accepting the range of assumptions and approximations in the various figures, this nonetheless highlights how consumer equipment, whilst individually having relatively small impacts in terms of manufacturing and operational energy use, have very significant impacts owing to the very large quantities involved and their shorter product life compared to infrastructure systems, and thus the importance of addressing manufacturing and operational efficiency of consumer products.

Please refer to Appendix C for further discussion and data examples from the surveyed studies, together with commentary on the Defra MTP (Market Transformation Programme) and EU Energy
using Products (EuP) activities, and studies on FTTx networks by the FTTH council and ITU.

### Smart2020 Data - Global

<table>
<thead>
<tr>
<th></th>
<th>MtCO2e 2002</th>
<th>MtCO2e 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global CO2 emissions</td>
<td>40,000</td>
<td>51,900</td>
</tr>
<tr>
<td>without abatements</td>
<td></td>
<td>with all abatements: these include 7800 indirect abatements enabled by ICT</td>
</tr>
<tr>
<td>Total ICT footprint (Smart2020)</td>
<td>530</td>
<td>1,430</td>
</tr>
<tr>
<td>% of Global emissions</td>
<td>1.3%</td>
<td>2.8%</td>
</tr>
<tr>
<td>% of Global emissions (2002)</td>
<td></td>
<td>2%</td>
</tr>
</tbody>
</table>

### Telecoms Infrastructure & Telecoms Devices

<table>
<thead>
<tr>
<th></th>
<th>MtCO2e 2002</th>
<th>MtCO2e 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile telecoms</td>
<td>66</td>
<td>179</td>
</tr>
<tr>
<td>Fixed narrowband</td>
<td>64</td>
<td>70</td>
</tr>
<tr>
<td>Telecom devices</td>
<td>18</td>
<td>51</td>
</tr>
<tr>
<td>Fixed broadband</td>
<td>4</td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>349</td>
</tr>
</tbody>
</table>

### Percentages of Total ICT

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile telecoms as % of total ICT</td>
<td>12.5%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Fixed narrowband as % of total ICT</td>
<td>12.1%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Telecom devices as % of total ICT</td>
<td>3.4%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Fixed broadband as % of total ICT</td>
<td>0.8%</td>
<td>3.4%</td>
</tr>
<tr>
<td>Total telecoms</td>
<td>28.7%</td>
<td>24.4%</td>
</tr>
</tbody>
</table>

### Percentages of Total Telecoms

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile telecoms as % of total Telecoms</td>
<td>43.4%</td>
<td>51.3%</td>
</tr>
<tr>
<td>Fixed narrowband as % of total Telecoms</td>
<td>42.1%</td>
<td>20.1%</td>
</tr>
<tr>
<td>Telecom devices as % of total Telecoms</td>
<td>11.8%</td>
<td>14.6%</td>
</tr>
<tr>
<td>Fixed broadband as % of total Telecoms</td>
<td>2.6%</td>
<td>14.0%</td>
</tr>
</tbody>
</table>

### Table 3.1. Smart 2020 data for global CO2 emissions: global ICT, telecoms

<table>
<thead>
<tr>
<th>Subsector</th>
<th>MtCO2 2005</th>
<th>MtCO2 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile networks, manufacturing, operation</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Mobiles phones, manufacturing, operation</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td><strong>Mobile Telecom - Total</strong></td>
<td><strong>50</strong></td>
<td></td>
</tr>
<tr>
<td>Fixed networks, operation</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>User equip. operation</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Fixed Telecom - Total</strong></td>
<td><strong>85</strong></td>
<td></td>
</tr>
<tr>
<td>PC operation</td>
<td>134</td>
<td></td>
</tr>
<tr>
<td>PC manufacturing</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td><strong>PC Industry - Total</strong></td>
<td><strong>214</strong></td>
<td></td>
</tr>
<tr>
<td>Data centres, operation</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Data networks inc. transport, operation</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Data centres &amp; networks, manufacturing</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td><strong>Data Networks - Total</strong></td>
<td><strong>154</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ICT Total</strong></td>
<td><strong>503</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3.2. Total CO2 emissions from Ericsson study 2008, ICT and E&M sectors

<table>
<thead>
<tr>
<th>Subsector</th>
<th>MtCO2 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVs &amp; TV accessories, operation</td>
<td>350</td>
</tr>
<tr>
<td>TVs &amp; TV accessories, manufacturing</td>
<td>100</td>
</tr>
<tr>
<td>Other E&amp;M hardware, operation &amp; manuf.</td>
<td>110</td>
</tr>
<tr>
<td>Paper industry and printers &amp; copiers</td>
<td>240</td>
</tr>
<tr>
<td><strong>Entertainment &amp; Media - Total</strong></td>
<td><strong>880</strong></td>
</tr>
</tbody>
</table>
4 Assessing impacts

We now consider the issue of how the impacts of communication systems may be assessed, to provide insight into how this process may be undertaken and prioritised and the challenges involved. We conclude with a summary of the key steps needed in the generic case, with elements of these steps illustrated as part of the communication system case studies in Section 5.

The analysis work performed both during this study and in the industry studies reviewed as part of the literature search, highlight the following key issues in understanding the environmental impact of communications systems:

- The importance of defining what comprises a ‘communication system’ for the purpose of a given evaluation, to help ensure that the understanding and results gained are relevant and appropriate to the requirement
- That it may be necessary to distinguish between and evaluate in different ways, the physical parts of a system, the key underlying technologies that may be used, and the services and applications supported or provided by that system
- That different types of environmental impact may be associated with different aspects of a system; e.g. direct impacts and energy usage typically relate to physical equipment and products, whilst ‘indirect’ impacts such as reductions in the environmental impact in other (non-communications) sectors, may be influenced by the services provided by the communications system
- That it is important to define the purpose of and the information desired from a given environmental evaluation, in order that the appropriate system scope, analysis depth and quantitative accuracy needed may be determined and the feasibility and limitations of an analysis be understood.

We now consider these issues further.

4.1 Defining systems, technologies and services

A complete communications system typically encompasses many different elements or sub-systems that combine together to deliver the overall desired functionality. These will include a wide range of hardware, software, protocols and algorithms to implement each part of the complete system.

For physical system elements, different parts of the system will have significantly differing environmental impacts (usually 1st order direct, negative, impacts) - both in terms of operational or ‘use phase’ impacts (e.g. energy consumed when active, in standby, etc), and in terms of whole life cycle impacts (manufacturing, delivery, installation, maintenance and disposal).

Functional ‘non-physical’ parts of a system such as the applications, services and software functionality that it supports, can also have significant but widely different environmental impacts, both 1st order (negative) and 2nd/3rd order (positive or negative).

Attempting at the outset to include all the physical elements of a communication system into an environmental analysis, as an all-inclusive (“bottom up”) approach, is very likely to prove time-consuming, unwieldy and/or impractical.

4.1.1 Systems architecture approach

A more efficient and structured approach is thus needed, using a simpler method based on first identifying the most important elements in terms of their environmental impact. These can then be
prioritised with subsequent more detailed assessment of those specific system elements that have greatest impacts. Less detailed estimation and aggregation of the impacts of the remaining system elements can then be performed if required, to gain a total system view.

It is thus useful to adopt a straightforward hierarchical systems approach to evaluating systems.

Taking a top-level view, a communication system comprises all of those elements needed to make it function as a whole, and to deliver the service(s) for which it is implemented. A system might, for example, include a transmitter network, user devices such as handsets or set-top boxes, a backhaul and fixed network (‘backbone’ or ‘core network’), central office billing and operational support systems, ducts/cabling/fibre, etc; everything necessary for the complete set of services to be delivered to users.

Each of these major system elements may be considered as a sub-system, each sub-system potentially being made up of further sub-systems. At the lowest level, sub-systems can be considered to employ different technologies to implement required functions.

Technologies may then be defined as those physical and engineering elements used to build sub-systems, which have specific characteristics in terms of materials and energy usage, which represent current states of technology development(s), and which have well-defined sets of operational characteristics (e.g. software protocols/programs affecting system energy consumption and efficiencies, on/standby times, etc).

For example, we may refer to current developments in cellular mobile base station power amplifier technologies, whilst a base station is a more generic sub-system, forming part of the infrastructure of a complete communications system delivering mobile phone services. Figure 4.1 gives an illustration of this approach.

For the requirements of a given environmental assessment, some elements of the complete system may not be of interest or be relevant. Communication systems that deliver, for example, satellite TV services or mobile voice services, will include operational ICT systems to support the running of the transmission networks. However it may be decided that these ‘sub-systems’ are out of scope for a given analysis, but may be included when an operator reports on their total environmental footprint (see ‘Identifying system scope for environmental evaluation’ below for further comment on system scope).
Figure 4.1. Systems and services approach to assessing impacts

Taking an initial top-level architectural view for a given assessment context helps ensure that major system contributions to impacts are not missed and can be included, or set aside if considered out of scope for a given evaluation requirement.

Analysis of the literature shows that this type of systems architecture approach is also adopted by many third party studies, even though the underlying analysis is not published in many instances.

4.1.2 System usage & sub-system quantities

In evaluating impacts, it is also apparent that account needs to be taken of the usage of the system in terms of the service(s) it provides and their related applications, and of the time periods that the system is operational - both shorter term in respect of daily usage, and in terms of the overall operational life.

Different elements of the system will have different types of impacts and to differing degrees, depending upon the overall architecture in terms of the type and quantity of sub-systems used, the individual impacts of the sub-systems, and, as noted, the types of technologies used to implement them.

The latter point about quantities is important. A sub-system such as a consumer device (e.g. a set top box) may have a small impact in terms of manufacturing or energy use for a single unit, but the quantity may be very large when used in the overall system, and the quantities may be forecast to vary over time.
Conversely, an element may have a larger individual impact (e.g. a television transmitter), but in practice there may be a small number making up the total system. Figure 4.2 provides a simple illustration.

![Figure 4.2. Individual impacts vs. quantities](image)

Thus in practice we find that:

- The total impacts of a system are normally strongly correlated to the number of users of the system, i.e. more users mean more infrastructure, more consumer equipment, etc. For example, the fixed telecommunications network has millions of users, whilst a marine radio system many fewer.

- The impacts of parts of a system may be weakly correlated to the amount the system is actually used in terms of subscribers or data traffic, i.e. significant parts of systems may be typically be consuming energy irrespective of user/traffic loading.

- The impact of consumer equipment can be very significant in terms of environmental impact, due to the very large quantities involved, even though individual unit impacts are small.

The second point is an area of improvement now actively pursued for certain communication system elements - including set top boxes (ensuring use of standby/sleep modes are optimised), mobile base stations (reducing power at night during light traffic loading), and DSL broadband (defining low power modes to reduce modem energy consumption when lightly-loaded).

To properly assess the impact of a system, it is therefore important to initially examine all the major architectural elements, and to evaluate, to a first approximate level, their likely impacts. This needs to take account of the quantities used, the actual or forecast numbers of users of the system over the life of the system, and (potentially) the expected improvements in technologies over time.

Once the likely major contributors are identified and prioritised, analysis effort can then be efficiently focused on these, and more detailed analysis of environmental impacts performed.

It is also important to note that there is not a single set of ‘environmental impacts’ that may be assessed in every instance. For a given assessment, the impacts of interest will depend upon the purpose and focus of that analysis. For example, the focus may be energy and related CO₂ emissions, waste, hazardous materials, manufacturing impact, or combinations of these.
4.1.3 Services-driven approach for second & third order impacts

The above approach is most applicable to quantifying 1st order impacts, i.e. those impacts arising from the direct manufacturing, assembly, installation, operation and disposal of physical parts of a system; the landscape or environment impacts resulting from the deployment of the system; or other related direct results of building and running the system (maintenance journeys, energy use by call centres or servers where applicable, etc). Analysis of first order impacts can be carried down relatively straightforwardly into individual sub-systems and underlying technologies as may be necessary.

For 2nd and 3rd order impacts, it is appropriate to take a services & applications-driven approach. It is the influence the services of a communications system may have on other applications, processes or behaviours that is relevant, and how the environmental impact of those applications, processes or behaviours is modified.

For 2nd order impacts, it is therefore necessary to identify the application or process that is enabled or affected by the system, and to then attempt to analyse the changes the system makes to the corresponding environmental impacts.

Similarly for 3rd order impacts, the activities and behaviours affected by the systems’ services need to be identified. Analysis or estimation can then be made of the degree (linkage) to which the services affect the activities and behaviours, and the changes in their environmental impacts then assessed to an appropriate level (ref: Figure 4.1).

System operation and usage is normally encompassed within the service definition, i.e. aspects such as the time(s) the system is actually operational/available.

In practice, it is apparent from our research that accurate second and third order analyses can be difficult to undertake, relying on a range of assumptions, particularly where change of behavioural or usage patterns is involved. This is discussed in more detail in Section 6 and Appendix B.4.

However such a ‘top-down’ approach to looking at systems architecture, services and applications is a useful, structured approach for addressing the problem, and particularly for 1st order (negative) impacts.

4.1.4 Identifying system scope for environmental evaluation

Building on the previous points and with further consideration of practical communication systems of various types, current studies, and simple first-level analysis, the following observations can be made:

- An inclusive ‘end to end’ approach to evaluating a system can lead to time-consuming and excessive analysis. Different parts of a given system will in most cases have different types and levels of impacts, with a few parts or sub-systems being the major contributors to the total impact (particularly depending on quantities of elements/subsystems, as discussed above). Therefore detailed analysis of these with less detailed analysis of the low-impact element of the system is a more practical approach.

- The sub-systems underlying a system may be complex, with different sub-systems fulfilling varied system functionality and composed of a diverse mix of technologies. Therefore simply attempting to evaluate the impact of a single technology can be inappropriate, as this will not reflect the full system, or potentially the way a technology is actually used within a given system.

The ‘end to end’ system to be considered in a given instance will also depend on the evaluation requirements, i.e. the overall purpose for which an evaluation is conducted - there may well not be a single, ‘definitive’ footprint and set of impacts for a given type of system.
For example, a television transmission network may need to be considered in one instance where this is perhaps being upgraded, vs. a complete new broadcasting system (including media generation and management systems, operational ICT and consumer devices), such as when a complete operational service is being considered, or where a broadcaster is reporting on their environmental footprint.

Further, when trying to assess a range of communication systems, either within scope of a given business operation (for example an operator providing fixed, mobile, broadband and TV services) or, in perhaps the full range of communication systems falling within Ofcom’s remit, the problem expands further, indicating that a ‘piece by piece’ analysis of each system is likely to prove impractical in very many instances.

The latter point is illustrated further in Table 4.1. During the study consideration was given to listing the wide range of systems that fall within Ofcom’s remit, and the table gives one example of such a (non-exhaustive) list, indicating the wide range of systems involved and reflecting the equally broad range of services provided, even without going to the next level and considering the major sub-systems involved in each.

Consideration of timescales is also important, whether this be in terms of planned system operational life overall, the lifetime of major elements and consumer devices, or in terms of the planned life of services and applications in the market.

As noted above it is therefore important to define the aim(s) of a given environmental evaluation at the outset, so that the appropriate parts of both the physical system, and the appropriate services and functions, can then be defined for inclusion. Defining the physical ‘scope’ of the system for the purpose of analysis is essential if meaningful results are to be obtained.

This is a key issue at present, when seeking to use results from studies already conducted. Different studies typically start with different baseline assumptions and with different definitions of what is included in the analysis and so may not be easily comparable, or may not be applicable (without careful interpretation) to a UK communications context.

Helping to address this and improve the consistency and comparability of analyses within the UK communications industry is one area that Ofcom might play a valuable role, and was highlighted in a number of the project discussions with industry stakeholders.
### Table 4.1. Example of ‘long list’ of communication systems within Ofcom remit

#### Satellite
- TV Broadcast - ATV, DTV, HDTV, …
- Corporate video and data transmission
- Radio Broadcast
- Telemetry
- Marine Emergency
- Data Networking Links
- Amateur Satellite
- Meteorological

#### Mobile
- 2G
- 3G
- 4G
- I-Burst Mobile Broadband
- TETRA
- Bespoke comms

- Telematics
- Aviation Mobile
- Aeronautical Radio navigation
- Maritime Mobile
- Maritime Radio navigation
- Radiolocation

- Bluetooth
- UWB
- Zigbee, 802.14.4
- GPS

#### Fixed Wired
- Telephony & Broadband
- Copper networks
- Fibre networks FTTH/FTTC…
- ADSL/xDSL…
- Cable TV
- NGN

#### Fixed Wireless
- Terrestrial Broadcast TV
- Terrestrial Broadcast Radio
- Radio Microphones
- Fixed Wireless Access
- Fixed Microwave Links
- Radar
  - Airport
  - Marine Fixed Radar
- Radio Astronomy
- Telemetry
- TETRA
- Digital Mobile Radio
- WiMAX (802.16d)
- Wi-Fi
- Standard Frequency/Time
- RFID
- Near Field Communications

#### ICT and Internet
- Servers & Server Farms
- Routers
- IT Systems, PCs, Wireless Printers…
- Enterprise ICT

#### Consumer Products
*may be considered as sub-systems*
- TVs
- Radios
- Mobile media players etc
- Wireless-connected Media Centres
- Mobile phones, Smartphones

### 4.2 Types of analysis

According to the overall context and requirements for an environmental evaluation, different types of environmental analysis can be adopted.

Three types of analysis in particular can be considered:

1. **Comparative analysis** - of systems performing similar functions and services, for systems being modified or upgraded compared to existing ones, or for comparison of systems to previous generations.

2. **Absolute impact analysis (individual systems)** - of individual systems (for example new systems and their services that are being planned or introduced), for which historic, baseline or other comparative data is not available, or for which existing data is not current. In practice, the major contributing sub-systems are identified and analysed in detail with remaining sub-systems being aggregated and estimated to less depth, so as to balance the
level of analysis accuracy for different parts of the system against time, effort and available data.

3. **Absolute impact analysis (many systems)** - for a large number of communication systems, in order to identify those with the greatest impacts, or to provide aggregated data for a range of systems of a given type, or for the sector as a whole. An example of this approach would be the need to identify a prioritised or ‘top ten’ list systems that have the largest overall impacts of all current communication systems. Once these are identified, it allows these biggest contributing systems to be analysed in greater detail, with the impact of remaining systems being aggregated and estimated to a greater degree than for the major contributors.

Comparative analysis (1) might be desired for evaluation of systems in competitive proposal situations for the introduction of a new type service against an existing one. Examples are digital TV vs. analogue, satellite TV vs. terrestrial TV, 3G vs. 2G mobile, or improving indoor 3G mobile coverage using macrocells or femtocells (see femtocell case study in Section 5.1).

However, in practice, absolute analysis as defined in (2) may still be necessary, in addition to or instead of attempting to perform a comparative analysis, as a result of the estimation and approximations typically involved. If the absolute impacts of a system are determined to be substantial, then actions to minimise and continually reduce them are worthwhile - even if the impacts can only be determined to a given accuracy. If absolute impacts are determined to be small, then there is a lesser environmental priority to address them. Minimising the absolute impacts of all systems is the key issue for Climate Change.

Trying to compare systems can lead to large uncertainties where the impacts are of a similar order, and particularly where it is not simple to compare system scopes and functionality.

The last type of analysis (3), applies (for example) were Ofcom to independently report on the total footprint and other impacts and advantages of the communications industry, for example as input to other Government reporting, or possible future EU requirements.

### 4.2.1 Evaluating 1st order and 2nd/3rd order impacts

When considering a given system, a system with relatively small 1st order (direct) impacts may nonetheless have significant potential 2nd/3rd order impacts which should not be overlooked. It should not be assumed that a system with small direct impacts necessarily has small indirect impacts. A wireless sensor system might comprise a modest amount of infrastructure, but have the potential to make significant reductions in commercial building energy consumption, for example.

Quantitative evaluations of 1st order impacts, such as use phase energy consumption and life cycle impacts, are also typically more readily assessed compared to quantitative evaluation of 2nd/3rd order impacts; the latter may therefore require a more qualitative assessment approach with greater context-specific assumptions.

### 4.2.2 Mobile TV example

Figure 4.3 provides a simplified example of the type of structured thinking needed when considering the potential environmental impacts of a system, in this example for the introduction of a Mobile TV service. The figure illustrates typical product (handset), system (infrastructure) and service (TV channels, new services) aspects that might need to be considered.

In an analogous manner to mobile voice/data communications, the number of competing mobile TV operators introducing a mobile TV systems would have a direct influence on the number of deployed base stations. But issues such as the amount of new infrastructure required (to achieve for example, desired coverage and service levels), vs. the use or sharing of existing infrastructure
sites, would also need to be evaluated. Once determined, this would then allow further system analysis to be conducted, based on hierarchical architectural approaches as previously discussed. Appropriate life cycle assessments (LCA) for the major contributing system elements would also be carried out as appropriate.

Figure 4.3. Example of simplified assessment approach, for a mobile TV scenario

Again, dependent upon the number of competing operators, and on the likely platform/technology model for how users will receive mobile TV, evaluation would then be made of the number of new handsets needed to be deployed, and the likely annual handset consumption/turnover over time. The use of existing mobile phones or other platforms to receive the new mobile TV service also needs to be considered - the environmental impact of these existing handsets may need to be set aside, if their impacts are already associated with other mobile systems.

It would be important to also consider technology standards for the system, to gain a view of likely technology evolution over the life of the whole system, so that likely improvements in energy consumption, manufacturing, disposal and other impacts over time can be factored in.

On the services and content side, careful evaluation is needed to assess if a new mobile TV service will simply add to existing services, or potentially reduce or increase consumption of existing services. Thus it may also result in 2nd/3rd order effects, such as the new service causing changes (for example) in behaviours in existing TV viewing. The new service might also contribute to an increase in consumption of other goods and services, for example increased sports product sales and activities as a result of new advertising and content channels.

It becomes evident that a substantial degree of analysis can be involved, depending on the depth of
analysis, the degree to which quantitative data is required, and the elements of the complete system that are deemed to be within scope of the assessment.

In practice, a combination of quantitative and qualitative assessment would be applied, balancing analysis time and effort against required depth.

### 4.3 Key steps in assessing impacts for communication systems

Drawing together the key points from this section and Section 2 on Environment Background, we can summarise key steps important to consider when evaluating the environmental impact of communication systems.

1. Clearly define the context and purpose for an evaluation, and the relevant environmental impacts (e.g. carbon emissions from energy usage, embodied carbon from manufacture and transport, materials waste, etc), to define the evaluation requirements.

2. Consider the appropriate type(s) of analysis to give the desired information and data estimates – i.e. detailed analysis of absolute impacts of a system, aggregated estimates for multiple systems, detailed comparative analysis of specific parts of similar systems, etc.

3. Given the evaluation requirements, define the physical & functional scope of the system(s) to be evaluated, e.g.
   - **Physical**: the entire end-to-end system, just the infrastructure and consumer elements, individual sub-systems (such as telecom exchange and street cabinet equipment), etc
   - **Functional**: applications, services and other non-physical aspects of the system that may have direct and indirect impacts, positive or negative.

4. Examine the system architecture and key sub-systems, and perform an initial qualitative and quantitative ‘pre-assessment’ of likely environmental impacts. Those parts with greater impacts can then be identified and prioritised for more detailed analysis, whilst those with lesser impacts can be set aside or aggregated/estimated more approximately.

5. Determine the appropriate geographic scope – e.g. just the UK for system operation (energy usage) and for the use and impact of services, but global for manufacture and disposal of sub-systems and consumer equipment.

6. Determine the relevant timescale for key system elements - e.g. the operational life for the infrastructure, the average life for consumer items, etc. (impacts from system operation may be determined on an on-going annual basis, but impacts from manufacture, implementation and disposal must be considered in terms of overall system life via life cycle analysis, LCA).

7. Identify key assumptions, drivers or constraints on deployment, usage and growth of the system and services, to inform more detailed analysis.

8. Specific detailed analysis of system elements and sub-systems with greater impacts can then be conducted, given the various factors identified above. Depending on requirements, the environmental analysis methods and techniques as are used more widely may be applicable, as introduced and discussed in Section 2 and in Appendices A and F.

Elements of these steps are illustrated in the case study examples in the next section.
5  Direct impacts – Case studies

The following example case studies help illustrate the thinking and approach that may be applied when considering environmental issues for communication systems, in particular to help demonstrate some of the processes introduced in Section 4.1 & 4.2. The aim is not to provide a definitive analysis in each case, but rather to introduce a typical process, the range of factors that might need to be considered and prioritised, and the ‘orders of magnitude’ of impact.

For 2nd and 3rd order (mainly positive) impacts, Section 6 provides a more detailed discussion of work identified from our analysis, with particular focus on travel-related impacts.

5.1 Case Study - Femtocells

5.1.1 Introduction

With the imminent introduction of femtocells\(^1\), it is instructive to compare their environmental impact with the (hypothetical) alternative option of expanding the 3G macro network\(^2\) to achieve a similar level of indoor coverage (see Figure 5.1.1). The comparison here concentrates primarily on the relative energy consumption of the base stations in the two approaches, but other environmental aspects will be mentioned.

There is currently a great deal of interest in the provision of enhanced 3G wireless coverage using femtocells. One of the key benefits of femtocells over, say, dual-mode 3G/Wi-Fi approaches (referred to as Unlicensed Mobile Access - UMA) is that standard cellular mobile handsets can be used.

Femtocells provide a number of potential benefits for network operators, including:

- Improved radio coverage indoors without a massive expansion of the network infrastructure, implying reduced capital expenditure
- Increased network capacity without an increase in the amount of spectrum needed
- Reduced customer churn as a result of the incentives mentioned below.

The cost savings that ensue are expected to be passed on to those customers who access services via the femtocell in their home in the form of:

- Reduced voice and data charges, the latter becoming increasingly important as broadband wireless data use accelerates
- Special tariff plans, especially if all members of the family subscribe to the same network operator.

Vendors will include the current suppliers of wireless infrastructure plus specialist manufacturers of small base stations such as ip.access, UbiquiSys and Airvana. Some IT and software companies, including Cisco and Google, have taken stakes in femtocell start-ups.

\(^1\) Femtocells are generally understood to be low power base stations (typically 13-20 dBm transmit power) for use in residential applications. The indoor base station is connected to a mobile network operator’s core network via a broadband IP connection such as ADSL.

\(^2\) The macrocell network provides the general, wide area, mobile cellular coverage. The familiar roadside cellular masts and antennas on tops of tall buildings are part of the macrocell infrastructure. Microcells might also be deployed by a network operator in areas of high demand, but these are generally sited below building roof level. So-called picocells and nanocells can be either operator-provided or customer self-provided and are typically used indoors in public areas such as airports or commercial premises.
Note that we are considering here the ‘closed’ femtocell case, where access is limited to the house occupants and visitors invited to use the femtocell. ‘Open’ femtocells, where the femtocell access is open to other users outside the home, are unlikely to be available for some time. The latter are of particular interest to network operators as they potentially offer a way of extending general coverage without installing more base stations.

5.1.2 Case study construction

5.1.2.1 Femtocell power consumption

Published estimates of the market for femtocell equipment vary, but for the purposes of this case study we will assume that the number of installed femtocells in the UK will reach 8 million, i.e. one femtocell device per four households.

If a femtocell device consumes 7 watts average power, say\textsuperscript{13}, the UK total femtocell power consumption would be 56MW or 490 GWh/year.

The above assumes that femtocells are operational 24 hours a day on the basis that it unlikely that users would wish to deactivate their femtocell if it provides the primary means of voice, messaging and data communications in their home. However, we note that there is work taking place aimed at sensing when devices are not active and automatically putting them into standby to conserve power.

\textsuperscript{13} It is envisaged that the femtocell device will combine the functions of a broadband router and Wi-Fi router as well as providing the low-power indoor 3G connection. Approximately 50% of UK households currently use a Wi-Fi router (Ofcom Communications Market Report 2008). Femtocell device energy efficiency can be expected to improve in the coming years, mainly as a result of higher levels of electronic circuit integration.
5.1.2.2 Indoor coverage and macrocell site density

For the purposes of making a comparison between femtocell and macrocell power consumption, the following will be assumed:

1. A high level of 3G macrocell geographical coverage might require 30,000 base stations per network operator (see Section 5.2). Figure 5.1.2 shows the extent of UK 3G coverage in 2008.

2. The radio power link budget is taken to be downlink-limited; that is to say the factor limiting coverage is the path from the base station to the mobile terminal. This is commonly the case in practice where the data flow is predominantly in the downlink direction.

3. The power link budget is set to achieve adequate outdoor and marginal indoor coverage at the cell edge. Any increase in building penetration generally has to be achieved by adding more cell sites.

4. The installed base of 3G base stations at the time when the femtocell market matures will each consume 500 watts (see Figure 5.1.3 and Section 5.2).

5. The current 2 GHz 3G band is of primary concern.

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Figure 5.1.2. UK 3G
(Source: Ofcom)

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14 For an uplink-limited link budget (which can apply, for example, when the mobile terminal battery power source is the limiting factor), the cell density would still have to be increased to improve indoor coverage, but the power consumption implications are different.

15 Other bands, from 800 MHz to 2.6 GHz, will be opened up for 3G use in due course.
The penetration loss of a typical UK dwelling at 2 GHz is usually taken to be around 16 dB\textsuperscript{16}. That is to say, 40 times the power is required to achieve the same signal level inside the house than outside. This figure has been borne out by Plextek’s own radio propagation measurements made in a variety of homes.

Using the scenario outlined above and further assuming (a) the dimensions of the house are very much smaller than the distance of the house from the serving macro base site and (b) the macrocell propagation follows a 4th power law outdoors (the ratio of the power received to the power transmitted is proportional to 10 log (1/d\textsuperscript{4}), where d is the distance from the cell site to the house), then the distance between base station sites would need to be reduced by a factor of 2.5 to maintain the link power budget for enhanced indoor coverage. This implies an increase in site density of x 6.3.

Whilst it could be argued that increasing the signal by an amount equivalent to the building penetration loss does not ensure that coverage will be good in all rooms of the house, it is also the case that a femtocell solution might not achieve good coverage everywhere as the antenna will be in a particular room.

### 5.1.2.3 Increase in energy use from additional macrocell sites

Increasing the cell density by a factor of 6.3 translates, to a first order approximation, to an increase in energy use by the same factor. So the increase in the total macrocell power consumption per operator is 80 MW or 700 GWh/year, giving 3500 GWh/year for five operators each with similar networks.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{nokia_base_station_power_demand.png}
\caption{Nokia Base Station power demand (W)}
\end{figure}

\textbf{Figure 5.1.3. Reduction in base station power requirements with time}
(Note: ‘Indoor’ here means an indoor macrocell base station cabinet)

\textsuperscript{16} See for example Andy Tiller, ‘Introducing Femtocell Successfully into the Home’, ip.access, July 2008
5.1.3 Energy comparison and conclusions

The analysis above, which is subject to assumptions and approximations, indicates that femtocells have an energy advantage ratio of about 7:1 over macrocell expansion. This result is perhaps not surprising as femtocells place the base station where the coverage is needed\textsuperscript{17}. However several other points need to be considered:

- Increasing the density of macrocells would, of course, also improve outdoor 3G coverage (as well as network capacity).
- The analysis is based on 3G coverage at the cell edge. Dwellings closer to the serving cell site can expect good or acceptable indoor coverage without a network upgrade.
- The envisaged femtocell device will incorporate other functions already provided by existing devices in the home such as Wi-Fi routers, so the incremental consumption will be generally lower than that estimated above, reinforcing the advantage of a femtocell approach. However, replacing millions of existing pieces of equipment has its own environmental consequences.
- Femtocells may well have the effect of off-loading macrocell traffic and hence could reduce the energy consumption of macrocells marginally.
- Femtocells obviate the need to increase the number of cellular masts (for indoor coverage purposes), so the visual impact is less. Also, for planning consent reasons, it would almost certainly be impractical to acquire the number of additional sites calculated in this case study.
- The analysis does not take into account all the network elements needed to support an expanded 3G network within the radio subsystem and core network. Neither does it consider the additional infrastructure elements in the core associated with supporting femtocells. However, the energy use of these additional elements is considered to be relatively minor as they are comparatively few in number\textsuperscript{18}.
- Other than implicitly from an energy use perspective, how the two approaches compare from an economic point of view has not been considered here. We note that a report on this topic has recently been published by Informa Telecoms & Media\textsuperscript{19}.
- Not all consumers will be able to use femtocells as a fixed broadband connection is a prerequisite and DSL or cable coverage of the UK is not 100%. Perversely, broadband availability may be least where existing 3G macro network coverage is also poorest.

We have only considered here the energy use of the equipment in operation. Other environmental life cycle impacts which should also be taken into account include equipment manufacture and disposal. There will also be second and third order environmental effects (positive and negative.) One example could be the extent to which enhanced indoor 3G coverage would enable more teleworking, and hence lessen the adverse environmental impact of travel. Whilst Wi-Fi plus GSM, say, can provide a similar teleworking capability, 3G will provide it in a more integrated and seamless fashion.

\textsuperscript{17} A similar conclusion was reached when comparing microcell and macrocell coverage (see Graham Maile, The Impact of UMTS, IBC Conference on Mobile Networks and the Environment, London, 5-6 June 2000).


\textsuperscript{19} ‘Mobile Broadband Access at Home: The Business Case for Femtocell, UMA and IMS/VCC Dual Mode Solutions’.
This work has only considered the energy use of base stations. It can be shown that based on normal patterns of phone charging\textsuperscript{20}, the power consumption of all the handsets using the system is less than that of the infrastructure. This assumption might cease to apply if phone usage increased by a factor of more than about four as a result of improved coverage and services.

### 5.1.3.1 Implications for Ofcom

As it stands, whether a network operator chooses to achieve enhanced customer coverage and service quality through macrocell network enhancements or by rolling out femtocells is largely a business matter for the operator. Having fulfilled its licence coverage obligations it is up to the operator to weigh up the investment and financial return profiles.

However, looking back, if femtocell technology had been available in 2000 and Ofcom’s mandate had included judging the pros and cons of alternative technologies from an environmental perspective, the regulator’s stance on coverage obligations in the 3G licences might have been different. On the same basis, looking ahead, femtocells might influence Ofcom’s position if operators wanted more spectrum to expand 3G services.

The case study also illustrates the care needed in defining the assumptions and ‘scope’ for any assessment, particularly when trying to perform a comparative environmental analysis between systems with differing architectures. A more detailed assessment should also cover:

- Other 1\textsuperscript{st} order environmental impacts
- 2\textsuperscript{nd} and 3\textsuperscript{rd} order impacts
- Techno-economic arguments
- Regulatory options.

In addition to the environmental aspects considered here, femtocell versus extended 3G coverage touches upon a number of issues that are already within Ofcom’s sphere of influence:

- A new market opportunity for communications equipment suppliers and service providers
- Consumer choice and competition
- Spectrum management and spectrum efficiency
- Broadband availability and the digital divide.

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\textsuperscript{20} See Ofcom Communications Market Report 2008, pp38-39: A typical phone on the market today, charged for three hours per day, and with the charger left plugged into the mains supply continuously, will consume approximately 7.5 kWh/year. Manufacturers are beginning to introduce chargers that sense when the battery is fully charged and reduce their power consumption to just a few hundredths of a watt.
5.2 Case Study – 2G & 3G Mobile

5.2.1 Introduction

To help illustrate how environmental issues may be considered for a mobile communication system, we next consider the environmental impact of cellular telephony systems in the context of systems similar in architecture and size to those deployed in the UK.

We derive baseline figures for the energy consumption of the existing 2G and 3G networks and identify trends in technology and engineering practices that are beginning to affect this consumption.

We discuss the potential future path of base station development, and highlight the metrics by which networks might be judged. We also discuss some hypothetical scenarios for alternative approaches to network deployment, specifically:

- Reducing the number of independent networks
- Technology sharing
- Adoption of 3G in the 900 MHz (and potentially UHF) bands.

As noted in the study Introduction, it is not the intention within the scope of this case study to model the actual UK networks, but the figures used and the related discussion may be considered broadly representative of the UK.

5.2.2 Scope of environmental issues

As the main body of this report has highlighted, there are many aspects of environmental impact that might be considered. In the context of mobile telephony these are:

a) For both the network infrastructure and the user terminals, the overall life cycle environmental impact comprising:
   - The use of raw materials
   - Energy consumption of manufacture
   - Energy consumption of transport and distribution
   - Energy consumption of usage
   - Energy consumption of disposal, and the physical disposal of waste.

b) In addition for the network infrastructure:
   - Land usage for base stations and switching centres
   - Visual impact of base stations.

In the study literature search (Appendix B) we identified some of the extensive research in the area of the total life cycle analysis (LCA) of mobile communications, citing papers by Scharnhorst, Ericsson, Nokia, ESU/Faist, et al. This research indicates three primary areas of concern, regarding carbon footprint:

- The use-phase energy consumption of mobile phones
- The manufacturing phase of mobile phones
- The use-phase energy consumption of the cellular network, which is dominated by the use-phase of the radio interface (the BTS and NodeB).
5.2.3 Mobile handset impacts

The use-phase of mobile phones is considered by some researchers to be a significant element of overall system consumption, but only on the basis that the majority of it is due to the standby power of chargers which are not unplugged when not in use. The standby power is significant for older transformer-based chargers, but these are being superseded by latest generation switch-mode and ‘smart charger’ technologies (which adopt more intelligent charge sensing and standby functions). We therefore consider the use-phase of the phone to be a diminishing issue.

The carbon footprint associated with the manufacture of mobile terminals is a particular issue because of the high volume of products and the high churn rate – many having a life span of only one or two years in developed markets such as the UK.

An analysis of the carbon footprint of the mobile communications and ICT sectors by Ericsson\textsuperscript{21} concluded that the carbon footprint for the manufacture and operation of mobile phones was about 50\% of that for the network. A second report published by Nokia\textsuperscript{22} in 2005 combined a life cycle analysis (LCA) of a 3G phone conducted by Nokia and an LCA of a 3G network conducted by Ericsson. Two key results quoted are as follows:

- That the energy associated with phone manufacture was about 30\% of the use-phase of the network over an assumed two year phone lifespan and when normalised to CO\textsubscript{2} emission per year per subscriber. But this result is somewhat difficult to interpret because it is normalised to per-subscriber, which pre-supposes a figure for the number of subscribers supported by a given level of network infrastructure. As this figure varies the result will vary directly.

- That (3G) phone manufacture required (in 2005) around 150 MJ of energy per phone (equivalent to 42 kWh, or 24 kg of CO\textsubscript{2} emission). Amortising this figure over an average two year lifespan for the phone, and applying it to, say, 50 million handsets in the UK gives an equivalent energy consumption of 1000 GWh per annum – which is directly comparable to the approx. 1300 GWh for the use-phase of all the GSM and 3G base station sites in the UK as calculated in this case study Section 5.2.4.

The above figures serve to indicate the significance of phone manufacture that cannot be ignored in the overall analysis of environmental impact.

The use-phase energy consumption of the cellular network is a significant factor and is taken as the focus for this case study because it is one that can, to some degree, be influenced by strategies for spectrum allocation and licensing, and is also directly affected by technology advances. For these reasons we consider it of direct interest to Ofcom.

5.2.4 Network energy consumption

The use-phase energy consumption of any cellular network is centred on the macrocell and microcell base stations, because of their high quantity and low conversion efficiency into RF power. Within both, the primary power consumer is the radio transceiver.

Environmental data on network infrastructure products is limited in the public domain and so in this section we derive some estimates for equipment consumption so as to identify the key contributors and to provide an indicative calculation of total UK network consumption.

\textsuperscript{21} ‘Carbon footprint of mobile communications and ICT’, Malmodin, Ericsson, 2005

\textsuperscript{22} ‘Integrated Product Policy Pilot Project, Stage 1 Report’, Nokia, January 2005
5.2.4.1 GSM base station

Table 5.2.1 below illustrates some figures for two configurations of macro-site: a medium/high capacity 6/6/6 configuration\textsuperscript{23} as might be deployed for urban coverage and a low capacity 2/2/2 configuration as might be deployed for rural coverage.

We consider existing deployed equipment and so assume an efficiency of around 35\%\textsuperscript{24}. Tx output power is taken as 40W per channel (thus capable of delivering the ERP limit of 32 dBW). Ancillary items such as point-to-point microwave links, supervision equipment, etc. will vary site-to-site, but are relatively small energy consumers so we include a nominal figure for power consumption to cover such items. The figures indicate a total consumption in the region of 3 kW for the high capacity site, of which approximately 1.3 kW is dissipated as heat in the transmitter amplifiers, and nominally 30\% of RF output is lost in the interface to the antennas. Thus overall efficiency is in the region of only 17\%.

These figures compare reasonably with manufacturers’ data for deployed products. For example the Siemens BTS 240 (released in 2003) in an eight-channel configuration is quoted as consuming 1300W, thus a 6/6/6 site configuration would require three BTS240s each consuming approximately 950W, therefore giving a total of 2.8 kW. The Huawei 4th Generation BTS (released in 2007) in a 4/4/4 configuration is quoted as consuming 2000W.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
\textbf{Item} & \textbf{6/6/6 config.} & \textbf{2/2/2 config.} \\
\hline
Baseband ancillaries & 300 & 200 \\
TRX & 2200 & 700 \\
& 40W PA at 35\% effic. plus Rx chain & \\
BTS Consumption & 2500 & 900 \\
AC-DC power conversion & 370 & 130 \\
& at 85\% effic. & \\
Ancillaries (Microwave link, supervision, etc.) & 100 & 100 \\
Site Consumption & 3000 & 1130 \\
Air-conditioning (consumption = 30\% of cooling capacity) & 700 & 300 \\
Site consumption with air-con & 3700 & 1430 \\
\hline
\end{tabular}
\caption{GSM BTS Macro-site Power Consumption Estimates – Current Technology}
\end{table}

Table 5.2.1. GSM base station consumption for medium/high and low capacity configurations.

\textsuperscript{23} Using the nomenclature n/n/n to represent a three-sector site with n carriers per sector.

\textsuperscript{24} Early GSM transceivers had efficiency little better that 20\%, but the adoption of linearization techniques in recent years has permitted a harder Class-C biasing and so has brought efficiency closer to 40\%.
5.2.4.2 Equipment cooling

Of the 3 kW consumption estimated for the 6/6/6 configuration in Table 6.1, only 720W of RF power is generated: the rest being dissipated as heat. Air conditioning is typically dimensioned on the basis of it consuming 30% of its cooling capacity\textsuperscript{25}\textsuperscript{26}, resulting in around 23% additional overhead on overall base station consumption.

Where the BTS is deployed in an equipment room together with other telecoms equipment, air conditioning will normally be used, but the more common deployment is in an outdoor enclosure in which case, for most European climates, heat exchanger cooling is sufficient to maintain equipment within operational limits, allowing for self-heating and internal temperature rise. (For guidance, the Central Europe climate model\textsuperscript{27} indicates that 25°C is exceeded for only about 3% of the year).

5.2.4.3 3G base station

As is the case for GSM, there is a range of site types varying from the single carrier omni to multi carrier sectored site. For the purposes of this case study we assume that the majority of 3G sites cover high population areas and so we focus on the single carrier tri-sector (1/1/1) configuration - which we define as having one TRX per sector. This is believed to be a common configuration in the UK since each of the UK operators currently has fairly restricted spectrum\textsuperscript{28} for 3G.

For W-CDMA, some early PAs had no form of linearisation and so had efficiencies little better than 5%. The advent of such techniques as feed-forward linearisation, digital pre-distortion, and more recently adaptive pre-distortion together with the Doherty architecture\textsuperscript{29}, have brought efficiency closer to 25% in recent years\textsuperscript{30}.

On this basis, for the purpose of assessing the existing deployments in the UK, we have chosen an efficiency figure of 15%, as being representative of equipment currently in use. Furthermore we have chosen the same power output (ERP target) as GSM.

The resulting consumption figures for a 1/1/1 (three TRX) site and a single TRX (omni) site are shown in Table 5.2.2, indicating a 1/1/1 site consumption in the region of 1450W without air-conditioning.

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\textsuperscript{25} ‘Air conditioning lexicon’, Stulz UK Ltd. http://uk.stulz.com/solutions/a-z-index/


\textsuperscript{27} ‘Energy efficient enhancements in radio access networks’, Edler and Lunderber, Ericsson Review No. 1 2004

\textsuperscript{28} Vodafone has 2 x 15MHz at 2100 MHz whilst T-Mobile, O2, Orange and 3 each have 2 x 10 MHz (excluding unpaired spectrum).

\textsuperscript{29} In a Doherty amplifier a class-AB amplifier (called the carrier amplifier) is placed in parallel with a class-C amplifier (referred to as the peaking amplifier).

\textsuperscript{30} Note: Vodafone quote ‘PA efficiency has progressed from around 9% in 2004 to 15% in 2007 and is now approaching 20%’. But others are currently claiming 30% efficiency for MCPA.
5.2.5 Total consumption of radio access network

Outline data on the quantity of macro base station sites in the UK is available on-line at Ofcom’s Sitefinder. From this data the total deployments at November 2008 were as in Table 5.2.3.

<table>
<thead>
<tr>
<th>Quantity of UK Base Sites (2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM-only</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Total Base Sites</td>
</tr>
</tbody>
</table>

Note: The ‘shared’ classification covers technology sharing and site sharing. A further breakdown of this is not available within the Ofcom data.

To facilitate developing example figures for networks representative of the UK, we make the following assumptions regarding the above data:

- That all the sites classed as ‘shared’ in Table 6.3 contain GSM technology, and that 50% of these contain at least two GSM systems. This then gives an estimated total of 50,000 GSM installations.
- That approximately 50% of the ‘shared’ sites contain 3G technology, and that 50% of these

31 www.sitefinder.ofcom.org.uk
contain at least two 3G systems. This then gives an estimated total of 24,000 3G installations.

- That the split between urban and rural sites is in the proportion 60:40 (this being derived from analysis of the site location data in Ofcom’s Sitefinder listing).

Note: Whilst the above assumptions may result in some instances of double counting, it is illustrative of the essential approach and given we are not attempting to undertake an explicit UK analysis in this case study

On the basis of the above, we derive an estimate for the total consumption of all the UK networks in the region of 1300 GWh/year. The derivation of this is covered in the following sub-sections.

Note that this estimate differs from one made by Lamour. Lamour quotes a figure of 736 GWh/year for a network comprising 12-15,000 tri-sector sites each equipped with both 2G and 3G. Firstly, it is noted that Lamour’s estimate assumes an unspecified degree of cooling is used, and secondly, he does not state the site configuration (in terms of the number of channels per sector) or the assumed age (and therefore energy efficiency) of the technology deployed. These factors probably account for the difference between the two estimates (and also help illustrate the care needed when assessing and comparing apparently similar data).

5.2.5.1 Total network consumption - GSM

To gain a reasonably realistic assessment of the UK networks without delving into the details of each site, we apply the two GSM base station types in Table 5.2.1 to the total UK deployment on the (greatly simplified) basis that the 6/6/6 site configuration is used in urban deployments and the 2/2/2 configuration is used in rural deployments.

On this basis the total consumption of the UK’s GSM networks may be estimated to be in the region of 110 MW (equivalent to 1000 GWh/year, or approximately 0.6 MtC02 per year) – without air conditioning.

Thus for a single GSM network operator, having an assumed 12,000 base stations, the total power consumption for base station installations alone is in the region of 28 MW (equivalent to approx. 250 GWh/year).

An illustration of factoring in air-conditioning is derived as follows. Assume that an air conditioning unit consumes 30% of its cooling capacity. Then, if one assumes that as many as 25% of sites have air-conditioning activated for as much as say two months of the year when temperatures are high, the additional consumption per operator would be in the region of 250 x 0.25 x 0.17 = 11 GWh/year, equivalent to approximately 5%. On the basis of this we make a working assumption that air-conditioning of base station sites is not a major item in the UK.

5.2.5.2 Total network consumption – 3G

Taking the figure of 24,000 3G NodeB derived earlier, and on the basis that the deployment is a 1/1/1 configuration then the total consumption of all the UK’s 3G networks is in the region of 35

33 The average figure used is the ‘grid rolling average’ of 0.562 kgCO2 per kWh as specified in the 2008 guidelines to Defra GHG conversion factors.
34 In practice air-conditioning requirements of base station sites is dependent upon a range of factors and accurate calculation requires detailed site information.
MW (300 GWh/year), or nominally 7 MW per operator of 5000 sites.

This excludes microcell deployments and, of course, does not equate to the national coverage of GSM, both of which are discussed below.

### 5.2.6 Comparisons between GSM and 3G networks

Even at the low RF PA efficiency of 15% used above for the 3G NodeB, we see that the power consumption of high capacity 3G sites is considerably less than for GSM.

However, some notes of caution are necessary when comparing the figures for the complete networks:

- Current 3G coverage for each operator is in excess of 80% population coverage (the licence obligation for the end of 2007), compared to current GSM coverage in excess of 97% population. Expansion of an existing 3G network to national coverage is discussed within the scenarios of Section 5.2.8 of this case study, which suggests that near national coverage at 2100 MHz could demand energy levels comparable to that for GSM1800, albeit at possibly twice the number of base station sites.

- On the plus side for 3G is the greater capacity of a 3G NodeB in comparison with a GSM BTS utilising the same amount of spectrum. This is discussed further below.

Realising the true capability of 3G in terms of its higher data rates requires the deployment of an under-laid network of micro-sites. This is discussed further below.

#### 5.2.6.1 Capacity comparison

Direct comparison of traffic capacity between 2G and 3G is complex and somewhat beyond the scope of this case study. There is limited published data on this, some of which can be difficult to interpret because of the differing types of service offered.

Complexity issues for 3G include the overheads required for single frequency operation and the extent of ‘cell breathing’ whereby the degree of base station loading affects coverage. Three dominant overheads are:

- Code multiplexing to reduce intra-cell interference: nominally a 25-30% overhead.
- Code multiplexing for infra-cell interference (sector-to-sector): nominally a 20-25% overhead.
- Margins for ‘soft’ and ‘softer’ handover. Normal planning practices aim to keep the overhead for handover below about 30-40%, and a typical figure is around 25%\(^{35}\).

Combining these overheads results in the net capacity of a 3G sectored site being about 40% of the theoretical maximum.

For GSM, a key ‘overhead’ is the frequency re-use factor. Through advances in coverage planning techniques and the use of frequency hopping the re-use factor can be reduce to as low as x 4 or x 3.

On this basis it is generally accepted that 3G can offer a spectral efficiency (bits/s/Hz) of about double that for GSM and that this improves further with the introduction of High Speed Packet Access (HSPA) transmission. Thus whilst it is generally accepted that 3G is about twice as efficient as GSM in terms of voice circuits, the capacity of 3G in practice depends on the type and level of data traffic.

5.2.6.2 3G microcell deployment

Typical consumption figures\(^{36}\) for a microcell unit delivering 5-10W RF output are still quite high, e.g. in the region of 230W, which is about 20% of a single-carrier three-sector macrocell site.

Taking the assumption that there are 5000 units per operator, microcells are currently adding only of the order of 20% to 3G network consumption.

But the effect on network consumption could be much higher in localised high-capacity deployments. For example, consider a typical 3G urban cell of up to 1.5 km radius (7 sq km) comprising a 3-sector NodeB delivering up to 384 kbit/s downlink data. The power consumption of this is around 1.4 kW (Table 5.2.2).

If this were under-laid with say 20 micro-cells each covering nominally 200m radius (0.1 sq km, i.e. deployed with no cell overlap) and capable of delivering an average 5 Mbit/s downlink (R’06 mean performance), requiring 5W RF output and consuming in the region of 200W, then we have a 4-fold increase in cell power consumption (albeit for a 12-fold increase in data throughput).

Thus it can be seen how subscriber-pull for the enhanced services of 3G will put pressure on deploying more network resources and hence increasing the carbon footprint. It is, therefore, desirable that this is offset by improvements in efficiency of microcell equipment.

5.2.7 Trends in energy consumption

5.2.7.1 Historical perspective

There has been considerable improvement in the efficiency of cellular technology since inception. This is graphically illustrated by analysis conducted by Ericsson for its own networks worldwide\(^{37}\). The results are reproduced in Figure 5.2.1 below, and show three key factors:

1. A more than 50% reduction in energy use per subscriber for GSM over the past 12 years since 1995.
2. 3G (W-CDMA) commenced life at approximately double the energy per subscriber.
3. GSM and 3G are now close to equality in terms of overall carbon footprint per equipment item per subscriber.

But these figures need careful interpretation because they are normalised to per-subscriber, and of course there have been substantial increases in the subscriber base over the period. However, to a first approximation one might assume that networks have expanded proportional to their subscriber base, and so these characteristics are reasonably indicative of the improvements in the energy efficiency of equipment over the period.

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\(^{36}\) Current micro-cell products from Andrew Corp, Fujitsu, Nokia, require nominally 200-250W for a 2 x 5W or 2 x 10W RF PA configuration.

A second useful study is that of the entire GSM and W-CDMA network in Switzerland conducted in 2004 by Emmenegger\(^\text{38}\). This provides a baseline total LCA for the GSM and 3G deployments at that time. (Note that at that time, the networks comprised of the order of half a million 3G subscribers served by 1000 base stations, and 3.3 million GSM subscribers served by 3800 base stations). Results are presented normalised to the throughput per Gbit of data. Relevant data for energy consumption of the use-phase of the networks are reproduced in Table 5.2.4, indicating that the aggregate consumption per Gbit for 3G was nominally double that for GSM.

<table>
<thead>
<tr>
<th>Element</th>
<th>3G network (kWh per Gbit)</th>
<th>GSM network (kWh per Gbit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base station</td>
<td>16.8</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Table 5.2.4. Annual electricity use per Gbit data throughput of the Swiss network, 2004. (Source: Emmenegger)

A useful benchmark to be deduced from the Ericsson and Emmenegger analyses is that at circa 2003-2005, the 3G service was operating at about double the energy consumption of GSM in terms of either per subscriber or per unit of data throughput. The choice of metric for such analysis is discussed further in Section 5.2.9.1 below.

\(^{38}\) ‘Life Cycle Assessment of the Mobile Communications System UMTS’, Emmenegger et al, 2004
5.2.7.2 Incentives for reducing network consumption

Whilst energy consumption - specifically non-renewable energy consumption and CO₂/CO₂e emission - has now become a major agenda item it is instructive to consider what the incentives are for manufacturers and operators to seriously address the issue.

We estimate that each of the four GSM networks in the UK is consuming approximately in the region of 250 GWh per year. Electricity charges have risen substantially over recent years. Using UK Government published data\(^39\) for grid-power energy costs the UK, the rate per kWh has increased from about 2.8 pence for ‘large’ users (2.4 pence for ‘very large’ users) in 2001 to 4.8 pence (4.0) in 2007, but is now possibly in the region of 6.7 pence (5.6).

So, at the ‘large’ user rates GSM base station energy costs will have grown from around £7 million to £16 million per year per operator over the past seven years, a current equivalent of about £1600 per site per year. The equivalent for 3G will be about £4 million per operator, or about £1000 per site per year.

High though these figures are, they are still only comparable to typical costs for site rental, leased-lines and annual maintenance. Hence the incentive for operators to address power consumption per se is still not great. On this basis operators are unlikely to swap out equipment just to reduce power consumption – the total life cycle cost of the equipment would not justify it.

Instead, the major drivers for reduced power consumption stem from overseas markets that lack a ubiquitous national power grid, and hence which must rely on renewable energy sources such as wind and solar-power. Much of the efficiency enhancements from manufacturers such as Nokia, Ericsson, Huawei, etc. are driven by this need to deploy cellular networks in regions were electricity must be generated on site. Developed countries such as the UK will therefore benefit from these advances, especially for new deployments and upgrades.

Alongside this operators have strong incentives to reduce the number of sites and to reduce maintenance requirements. And it is significant that in so doing they are in general introducing technologies that, as a secondary factor, reduce power consumption. Examples are:

- Masthead deployable RF power amplifiers to eliminate coax feeder loss. For which key drivers are:
  - extended range for the same RF power and receiver sensitivity (within the bounds of ERP limits), or
  - ability to use lower-power amplifiers, for reduced cost and/or increased reliability

- The use of multi-carrier power amplifiers (MCPAs) to eliminate the cost, space requirements, RF power loss, and potential frequency planning inflexibility of having to use RF combiners.

5.2.8 Improvement measures

Below we identify a number of technological approaches to reducing the energy consumption of base stations. Other measures associated with alternative approaches to network deployment and integration are discussed in the subsequent section.

5.2.8.1 Mast sharing

Mast sharing is a common feature of cellular deployments. Of course, the primary gains are a reduction in land usage and an easing of maintenance logistics. But it offers very limited economies in power consumption.

There are some economies of scale from larger systems for cooling, battery back-up, and power conversion, but the savings are not great.

5.2.8.2 Power-down during quiet periods

Specifically for GSM: turning off radio resource that is not required during reduced-traffic loading (off-peak times) leads to around 25% power saving. This is being pursued by suppliers (e.g. Nokia, Ericsson), often as merely a software upgrade to their installed equipment.

5.2.8.3 GSM transmitter efficiency

RF amplifier efficiency for GSM-GPRS and EDGE is well developed and one can expect only modest advances beyond the 35 - 40% efficiencies now being achieved.

Nevertheless other improvements can be expected - particularly as a result of greater product integration. For example, in 2006 Nokia announced its Flexi-EDGE base station module that is a highly integrated unit for masthead mounting. This is a 2-transceiver unit and Nokia claimed at its launch that it would enable a 4/4/4, 50W per carrier, configuration to consume only 1000W.

However, significant improvement can be expected with the introduction of the multi-carrier RF amplifier (MCPA) for GSM, whereby a single unit simultaneously handles a number of carriers. Suppliers such as Huawei and Motorola are now offering 2, 3, 4, and 6 carrier MCPAs and are claiming substantial improvement in efficiency. Precise figures are not yet easy to obtain but Huawei has suggested its 3-carrier MCPA could realise a 12/12/12 configuration consuming only 2000W, which is the same power as required for a 4/4/4 configuration using its current 4th generation equipment.

Additional benefits of the MCPA for GSM are:

- Elimination of combiner insertion loss
- Without combiners, mast-head deployment is facilitated (eliminating feeder loss)
- For GSM, MCPAs facilitate implementing frequency hopping at RF rather than at baseband, giving improved interference reduction and hence capacity.

As a further example: in 2008 Nokia announced its intention to reduce consumption of its GSM BTS module in ‘typical configuration’ from its current 800W to around 650W over the next two years. Unfortunately we have been unable to clarify what configuration this relates to and whether

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40 ‘Watch 2G network costs fall with Flexi-EDGE base station’, Nokia broadsheet, 2006
it incorporates MCPA technology.

5.2.8.4 3G transmitter efficiency

The linearisation, and hence efficiency enhancement, of single and multiple carrier amplifiers for W-CDMA continues to advance. Digital pre-distortion (DPD) and DPD together with the Doherty architecture give promise of wideband power amplifiers achieving the 35 - 40% efficiency now achieved for GSM-EDGE, within the next one or two years.

As an example of this progress, Nokia has stated its plans to reduce consumption of its 3G Flexi-Base Station from its present 500W to 300W.

One significant enabler in this area (relevant to 3G and GSM-EDGE) is the advent of open standards for base-station equipment and the Open Base-Station Architecture Initiative (OBSAI) in particular. In defining an interface at digital baseband, between the baseband and the RF transceiver module, OBSAI has enabled a new generation of power-efficient modules to be created. Perhaps more importantly, it has opened up free market competition in the RF module area and this is helping to drive up efficiencies. Techniques such as digital predistortion have now largely replaced feed-forward in modern base-stations and this has been enabled by OBSAI’s adoption of a digital baseband interface to an RF module, rather than an analogue IF.

5.2.8.5 Avoidance of feeder losses

We have seen that feeder loss can account for 30% (2dB) wastage of RF output power. Coaxial feeder cable technology is already advanced, so it is primarily the cost issue that dictates performance (attenuation figures range from 2.5 – 7 dB/100m at 900 MHz, and 5 – 10 dB/100m at 2100 MHz).

Masthead deployment of RF equipment is the primary solution here (of course, rooftop installations can already significantly reduce feeder losses). It is now being enabled by advances in the thermal resilience and reliability of equipment and is being pursued by a number of operators. (Examples for GSM are: the Nokia Flexi base station family for 2G and 3G, Huawei Remote Radio Unit (RRU3000 series, for 2G and 3G) and Motorola tower-mountable RBS2111 for 2G).

5.2.8.6 Hardware design for higher operating temperature

A significant contribution to conserving cooling power is to increase the permitted operating temperature of equipment. Clearly, an increase to 35 °C virtually eliminates the need for any air conditioning - certainly in the UK - and substantially facilitates ‘natural air cooling’. As an example of this, Vodafone-Portugal increased the operating temperature to 35 °C in all its 1100 base stations in 2007/2008, and claims a 25-30% reduction in cooling requirement.

5.2.8.7 Equipment cooling

An emerging technique for cooling is ‘natural air cooling’ or ‘open air cooling’, using filtered outdoor air. Such systems must take humidity, pollution, and corrosive gases into consideration and as such require each individual item of equipment to have improved sealing against such ingresses. Most of the major network providers are now adopting this approach, at least for new installations and upgrade. Vodafone and Motorola, for example, made this their default option for new deployments starting around 2007.

5.2.8.8 Summary of improvement measures

Table 5.2.5 summarises the energy consumption gains that might be achieved in the medium term expressed relative to a circa 2006 baseline. These improvements only apply to new installations and upgrades.
### Table 5.2.5. Indicative potential medium term energy consumption improvements

Caution needs to be exercised since (a) some of these gains will have been fully or partially realised in networks already and (b) not all the techniques mentioned are independent; the potential gains are thus generally less than that achievable by the sum of the individual measures.

Figure 5.2.2 summarises the trends in base station power consumption for the UK, normalized to ‘per subscriber’. The curves take into account the energy improvements discussed above, rolled out progressively, and they assume that these energy savings are averaged-out across base station sites in a network. The curves are intended to be indicative only and they assume that subscribers use either a 2G or a 3G network. In practice, of course, 3G subscribers will also use 2G when 3G is not available.

The enhanced 3G services curve represents the impact of introducing higher speed services based on HSPA. The following active subscriber numbers are assumed:

- GSM 2006 and 2012: 50 million
- 3G 2006: 6 million
- 3G 2012: 20 million

![Figure 5.2.2. Indicative trends in UK 2G and 3G network power consumption, expressed in terms of kWh/year/subscriber](image-url)
5.2.9 Scenario analysis

In this section we look at scenarios for changes to the UK cellular industry in order to illustrate their relevance to and impact on the carbon footprint issue.

5.2.9.1 Sharing and reduction in number of independent networks

It can be argued that multiple physical networks, resulting from multiple operators and a competitive commercial environment are an effective and/or necessary way to enable a new mobile market and can help drive technology developments. However, when assessing the energy use, land use, and visual impact of fixed networks it is evident that there can be a substantial impact in having several separate network deployments.

Network sharing is increasingly favored by policy makers as a way of addressing this conflict. On this basis the European Union has consistently ruled in favour of permitting network sharing and more recently also national roaming. ARCEP, the telecommunications regulator in France, has recently called for the country’s three 3G operators to reach agreement on infrastructure sharing by the end of 2009. If the operators cannot reach agreement, ARCEP will impose its own conditions. In addition to further passive infrastructure sharing (i.e. the sharing of sites, buildings and masts), ARCEP is calling for active sharing, either by sharing radio access networks (equipment sharing) or by 3G roaming (frequency sharing). The environmental benefits of sharing are given as a major reason for ARCEP’s decision.

The positive outcomes associated with active sharing include the following:

- More efficient use of spectrum and land
- Reduced use-phase energy consumption
- Decrease in the duplication of investment
- Improved quality of service, reduction of black spots, etc.

Vodafone and Orange announced\(^{43}\) a joint venture to share some of their 2G and 3G sites in the UK. The aim was for a potential saving of 3000 sites.

In a separate agreement\(^{44}\) Vodafone and Telefonica (O2’s parent company) have said that they will pool parts of their network infrastructures, initially in the UK, Germany, Spain and the Irish Republic. The companies said that the primary motivations for establishing the sharing agreement were to reduce operating costs, offer enhanced quality of service levels and reduce the environmental impact of networks by lowering the number of sites required by each company.

T-Mobile and 3 have estimated\(^{45}\) that by restructuring their combined 2G and 3G sites (a current estimated total of 18,000) they could maintain existing coverage with approximately 25% fewer sites, and could therefore re-deploy these resources to extend coverage. The operators are proposing to share three things: (i) equipment, such as the base stations, masts and cell sites, (ii) transmission from the cell site to the core network and (iii) site management. Trials have been ongoing throughout 2008 and the companies are planning to start site conversion in 2009 and complete it by 2011.

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\(^{44}\) http://www.airtimemanager.co.uk/news/index.php/2009/03/24/vodafone-and-o2-will-share-their-cell-towers/

5.2.9.2 Expansion of 3G to national coverage

For basic-level 3G services, e.g. data rates of about 384 kbit/s on the downlink at the cell edge, it is generally considered that the quantity of 3G sites required at 2100 MHz for 97% coverage would be similar to that required for GSM1800, possibly in the region of 12,000 sites.

If we further assume that the majority of these additional sites would be smaller capacity NodeB for rural infill, comprising say a single TRX unit distributed between sectored antennas then consumption would be in the region of 700W (Table 5.2). Thus the additional 7000 sites equates to an additional 5 MW per operator, bringing total consumption to about 12 MW (100 GWh/year) per operator, or 60 MW (500 GWh/year) for all five operators.

But even at a level of, say, 12,000 sites nationwide, such a 3G network (at 2100 MHz) would only provide a basic level of service. It is generally accepted that a further two- or three-fold increase is base stations might be required for a comprehensive level of 3G services: therefore, possibly in the region of 30,000 macro-sites. This would bring the energy consumption figure up to 30 MW (240 GWh/year) per operator, comparable to that for GSM.

The problematic nature of complete national coverage in terms of capital cost, and in terms of environmental impact, can be considered justification for considering the use of the 900 MHz band for 3G. As an example, Elisa of Finland recently concluded\(^{46}\) that it could save up to 70% on its build cost by deploying UMTS900 compared to UMTS2100.

Published data from a number of sources (Ovum\(^{47}\), GSMA\(^{48}\), Ofcom\(^{49}\), Huawei\(^{50}\)) indicate that the coverage area from UMTS900 cell sites can be 50-250% greater than for UMTS2100, the variability in this figure being a function of the propagation environment. This allows a dramatic reduction in the number of sites required – especially for rural coverage.

In conclusion, deploying 3G at 900 MHz (or at lower frequencies in the case of spectrum made available by TV digital switchover) instead of 2100 MHz would mean approximately a two- or three-fold reduction in the number of new base sites for rural coverage and hence a reduction in the use-phase power consumption roughly in the same proportion. Caution has to be exercised, however, as this presupposes that sufficient spectrum is available to support the capacity requirements in the new bands.

5.2.10 ‘Benefit’ versus Impacts

5.2.10.1 Benefits by coverage, capacity, services

Consideration of total energy consumption is clearly important; however it is also necessary to assess what is the return on this. The return can be judged in terms of area coverage, network capacity, subscriber base (number of subscribers), and service provision. As noted, some researchers choose to normalise carbon footprint analysis to ‘per-subscriber’, whilst others choose to normalise it to per-unit of data throughput. The choice of metric is important to the interpretation of the environmental impact issue. Below we identify four metrics that might be considered:

\(^{46}\) ‘GSMA Case Study’, Elisa, Finland, September 2008.


\(^{49}\) Application of Spectrum Liberalisation and Trading to the Mobile Sector, Ofcom, UK, September 2007.

\(^{50}\) Huawei contribution to UMTS Forum Workshop, June 20, 2007 (Also, ‘Deployment of UMTS in 900 MHz band’, UMTS Forum White Paper, October 2006 as ref. 89).
a) **Geographic coverage - Energy consumption per sq km covered per MHz of spectrum**

This is the efficiency of wide area coverage, and is primarily governed by operating frequency.

In this context the ‘value’ of GSM900 for rural coverage is high, since it is capable of giving adequate service type(s) for near 100% of the population; as compared to the impracticalities of attempting to cover the entire UK with 3G at 2100 MHz.

b) **Population coverage - Energy consumption per subscriber accessed per MHz**

This is the metric is chosen by Ericsson in many of its publications, such as the trend curve in Figure 5.2.1.

It is related to geographic coverage but is also influenced by system capacity. Thus, in contrast to requiring low carrier frequency for efficient geographic coverage, the supportable subscriber base can improve at high carrier frequency since it permits greater frequency reuse.

c) **Capacity - Energy consumption per unit of throughput per MHz – voice and data**

This is the metric chosen by Scharnhorst, Emmenegger, and others.

This is not too difficult to parameterise for voice, but is far harder for data because of the dependence on service type (data rate, error resilience, acceptable delay, etc.)

Comparisons between GSM-EDGE and 3G Release 99 (R’99) are reasonably straightforward because both are capable of providing services up to 384 kbps at the cell boundary. But complexity arises for 3G because the higher data rates of Release R’04 (up to 1.92 Mbit/s) and R’06 (up to 14.4 Mbit/s) are more range restricted.

As the example given regarding 3G microcell deployment (Section 5.2.5) helps to illustrate, the energy-per-bit metric can begin to look very attractive when a large number of small cells are considered, given that capacity increases significantly compared to the increase in energy consumption (x 12 vs. x 4 in this example).

d) **Service types offered - voice, messaging, web browsing, audio/video downloads, etc.**

Although much more difficult to assess quantitatively, the breadth, levels and richness of services enabled by a given technology (such as those possible with 3G compared to GSM) are also important to balance against the corresponding environmental impacts, and should be carefully considered alongside more direct measures such as those mentioned above.

5.2.10.2 **Visual Impacts**

Whilst for the purpose of this case study we are considering primarily energy consumption, it is a useful point to remember that other major impacts should be considered in any environmental evaluation, to give a balanced picture of environmental benefits vs. impacts.

Visual impact of the cellular network has been a significant public-relations issue. The typical multi-sector macro-site for GSM, either on a mast or on top of a building, has high visual impact. Site sharing can reduce the quantity of these around the countryside but will often only worsen the impact of each site.

There are some examples of ‘disguised’ antennas, specifically the ‘tree’ look-alike but these are not widely used because they compromise performance and are expensive. As networks (2G and 3G) deploy more low power sites to add capacity or coverage in-fill, particularly in urban/sub-urban areas, highly integrated antennas are frequently used. Examples of lower-impact antennas are shown below:
An example of a masthead mounted base stations is shown below, in this instance a mast using Nokia Flexi BTS equipment mounted on an open tower. Whilst the visual impact at antenna level might not be very different to that of a conventional mast configuration, this site benefits from the absence of a cabinet at ground level (as well as the energy consumption improvements that result from the elimination of feeder losses).

5.2.11 Conclusions on 2G & 3G mobile

Subject to the assumptions made, we can draw a number of conclusions as follows.

- The carbon footprint of cellular mobile networks is undoubtedly substantial within communications systems as a whole, with the contribution from base stations being the dominant factor. Our study illustrates that the total annual energy consumptions for base stations broadly representative of those currently deployed in the UK are of the order of 1000 GWh for GSM and 300 GWh for 3G - implying associated carbon footprints of approximately 0.6 and 0.18 MtCO₂ per year respectively.

- The prospects for reducing environment impact through continued technology innovation are good. Key progress areas include the advent of higher efficiency RF power amplifiers,

ruggedised amplifiers which facilitate masthead deployment and eliminate RF feeder losses, multi-carrier power amplifiers, and greater control of standby-mode operation of sites during periods of low traffic.

- A scenario whereby existing 3G coverage is expanded to UK national coverage (to greater than 95% population) indicates that this would require substantial increase in the number of base sites, possibly to in the region of 30,000 per operator, if comprehensive 3G services were to be available. In this respect one clearly sees the importance of operators combining their efforts through network sharing, and the potential adoption of UMTS900 (and possibly DDR UHF frequencies).

- While the energy consumption of 3G base stations is now generally at least as good as 2G base stations (for an equivalent number of voice circuits and at the same carrier frequency), the growth in 3G broadband mobile data services is a significant environmental issue. Subscriber-pull for the full range of 3G high data-rate services will put substantial pressure on deploying more network resource at macrocell and microcell levels.

- The study shows the importance of choosing appropriate metrics when evaluating the ‘benefits’ of networks, specifically in terms of the subscriber-base reached and the services offered in return for their carbon footprint. The choice of metric such as CO₂ emission per subscriber; per unit of data; per service type, etc. is important when comparing systems and technologies.

- With regard to handsets, whilst having a relatively low use-phase impact in terms of energy consumption, they have a substantial impact when overall life cycle factors are considered (manufacture, distribution, disposal/recycling). As a result of the short use-phase (typically 1-2 years for a significant proportion of handsets in the UK), the handset life cycle energy spread over the handset life is of a similar order to the network energy consumption.

**Policy issues**

- The penalty in terms of carbon footprint and visual impact of having multiple operators is clear from the analysis. Network sharing would reduce the environmental impact of networks (as well as the cost of network expansion). Several passive network sharing initiatives are underway, but the biggest opportunities to save energy come from active sharing.

- Running parallel GSM and 3G networks has an environmental consequence, but this is difficult to quantify as the migration strategies of the network operators differ. Whether there is an optimum cut-off date for completion of the migration from an environmental perspective, taking into account network energy efficiency, network and handset embodied carbon, material use and equipment disposal, plus economic considerations, is an area that might benefit from further study.
5.3 Case Study – Digital TV

5.3.1 Introduction

In this case study we consider some of the environmental issues relevant to delivering digital TV channels, taking the specific cases of delivery via a digital terrestrial network and via satellite. As part of this, we consider in particular the use-phase energy consumption for the terrestrial transmission network, including the legacy analogue network, the current (transitional) digital network, to the ‘full power’ DTT network that will be fully operational in 2012.

As for the other case studies, the aim is not to provide definitive results for the UK networks or for potential satellite delivery scenarios, but rather to help demonstrate the type of approach and thinking that may be needed and the scale of impact for such networks.

5.3.2 Context for terrestrial broadcast

At present there is a wide range of options available for receiving broadcast television services in the UK. A high percentage of the population have had a choice of receiving television via terrestrial or satellite for many years now. In urban areas the deployment of cable is widespread and popular. More recently, a number of broadband providers (BT Vision, Tiscali TV, Virgin Media On Demand) have launched IPTV services of various kinds using their networks for delivery.

These diverse methods of delivering television content have been effective in fostering competition and innovation in the market. The launch of Freesat opens up the availability of subscription-free multi-channel television to households unable at present to access Freeview: this means that virtually everyone can, in principle, obtain such a service if they wish. Another recent development is the emergence of High Definition (HD) service from Sky, Virgin Media and Freesat, with Freeview scheduled to launch HD services from 2009.

From an environmental point of view, these multiple methods of content delivery beg the following questions:

- What are the relative environmental impacts of these methods of delivery? Do any appear to be especially better or worse than the others?
- Is the number of delivery systems in itself excessive, causing a level of environmental impact that is not justified by the improved competitive scenario or service differentiation achieved?

Given the four major methods of content delivery, and the differentiation in services offered, these questions merit a major study in their own right. However in this case study we consider a subset of the above problem: what are the relative environmental impacts of Digital Terrestrial Television (DTT) versus direct-to-home (DTH) satellite broadcasting. Even with this restriction, comparing these two delivery methods is still of high interest for the following reasons:

- Both of these content delivery methods can potentially address almost all of the UK population: Ofcom is planning\(^52\) the DTT rollout to cover 98.5% of households with the core Public Service Broadcast (PSB) channels; whilst Sky claims 98% coverage on its website. The other methods at present are (broadly) restricted to towns and cities and thus do not easily meet full coverage of the population.
- The services currently offered over satellite and DTT are substantially equivalent in

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\(^{52}\) ‘Planning Options for Digital Switchover’, Ofcom, 1 June 2005
functional terms, being dominated by broadcast television. There is therefore the potential freedom to significantly change the mix, or in an extreme theoretical scenario, to eliminate one system entirely, were there a powerful enough incentive to do so. This would be much harder to contemplate if the two distribution systems were to offer very different service profiles.

As part of this project, Astrium EADS presented some of its views on the environmental impact of communication systems. Astrium indicated its belief that there is a strong technical and environmental case for moving terrestrial broadcast infrastructure to space, and also questioned whether there is a need for competition or choice at the infrastructure level, given that duplication of infrastructure may come at a high environmental cost. We therefore explore some of the issues in this case study, consider some of the environmental impacts of the two systems and perform some comparison to test the above points. Results and conclusions are summarised in Section 5.3.10

5.3.3 System scope

As noted above, we choose to consider here the primary transmission part of the TV delivery chain, i.e. the system needed to deliver multiple TV channels to the end consumer. Thus the system under consideration comprises primarily the transmitter and relay network and the consumer equipment (in the case of terrestrial), and the uplink transmitter, satellite and consumer equipment (in the case of satellite). To a first order, the ‘distribution’ networks may be considered out of scope and common to both, distribution networks being those that distribute signals to the transmitters. The rest of the TV production chain is similarly taken to be out of scope.

This is clearly a simplification, but immediately illustrates the importance (as noted in Section 4) of defining clearly the system ‘scope’ for the purpose of an evaluation, to ensure equivalent functional elements are sensibly compared.

5.3.4 Operating power consumption

5.3.4.1 User equipment power consumption

One of the obvious sources of possible environmental impact is the operating power consumption of the user equipment. Whilst the per-unit power consumption may appear quite low there is a high multiplier in terms of volumes, and the usage profile in terms of hours per day (operational and standby) is significant.

In 2005 the then departments of Culture, Media and Sport (DCMS) and Trade and Industry (DTI) commissioned a Regulatory and Environmental Impact Assessment of the digital switchover project. This includes both pessimistic (Scenario 1) and optimistic (Scenario 2) estimates of set-top box power consumption.

In 2005 Scientific Generics also produced a report on the cost and power consumption implications of digital switchover. This contained a power consumption evaluation of some of the equipment then available, based on Scientific Generics’ own measurements.

53 ‘Astrium EADS Telcon/Meeting Note’, GGW0201, Graham Maile, 19 September 2008
54 ‘Regulator and Environmental Impact Assessment: the timing of digital switchover’, DTI/DCMS, 15 September 2005
55 ‘Cost and Power Implications of Digital Switchover’, Scientific Generics for Ofcom, 8 November 2005
To obtain a more up-to-date view, power consumption test data from Ricability was reviewed and collated. Ricability is the Research Institute for Consumer Affairs, founded by Which? more than 40 years ago: it is a national research charity dedicated to providing strictly independent consumer research and information. The Department for Business, Enterprise and Regulatory Reform commissioned Ricability to support the digital switchover programme by producing independent consumer test reports on digital TV products.

Tables 5.3.1 and 5.3.2 show some power consumption figures from the above three sources, for DTT and satellite digital set-top boxes. The kWh/year figures assume an average of 4 hours usage per day as per the DTI/DCMS report.

Considering the DTT case in Table 5.3.1 first, we observe that in 2005 the measurements made by Scientific Generics were fairly consistent with the DTI/DCMS Scenario 1. The Ricability average figures indicate that substantial progress on power consumption has been made in the intervening three years although the DTI/DCMS Scenario 2 power consumption levels are still to be achieved.

<table>
<thead>
<tr>
<th>Source</th>
<th>Operating power consumption (W)</th>
<th>Standby power consumption (W)</th>
<th>kWh/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Generics report 2005, Table 3, Average Value</td>
<td>10.5</td>
<td>7.1</td>
<td>67.2</td>
</tr>
<tr>
<td>Scientific Generics report 2005, section 6.3, projected 2012 value</td>
<td>3</td>
<td>2</td>
<td>19.0</td>
</tr>
<tr>
<td>DTI/DCMS report 2005, Scenario 1</td>
<td>9</td>
<td>6.5</td>
<td>60.6</td>
</tr>
<tr>
<td>DTI/DCMS report 2005, Scenario 2</td>
<td>8</td>
<td>2</td>
<td>26.3</td>
</tr>
<tr>
<td>Ricability November 2008 (Average of 19 units reviewed)</td>
<td>6.4</td>
<td>4.6</td>
<td>43.0</td>
</tr>
</tbody>
</table>

Table 5.3.1. DTT set-top box power consumption figures

<table>
<thead>
<tr>
<th>Source</th>
<th>Operating power consumption (W)</th>
<th>Standby power consumption (W)</th>
<th>kWh/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Generics report 2005, Table 3, Average Value</td>
<td>16</td>
<td>12</td>
<td>111.0</td>
</tr>
<tr>
<td>DTI/DCMS report 2005, Scenario 1</td>
<td>N/A</td>
<td>N/A</td>
<td>157.4</td>
</tr>
<tr>
<td>DTI/DCMS report 2005, Scenario 2</td>
<td>N/A</td>
<td>N/A</td>
<td>88.04</td>
</tr>
<tr>
<td>Ricability November 2008 (Average of 3 units reviewed excluding Humax FOXSAT)</td>
<td>11.9</td>
<td>11.2</td>
<td>99.2</td>
</tr>
<tr>
<td>Ricability November 2008 (Humax FOXSAT - HD/GB reviewed)</td>
<td>16.2</td>
<td>0.9</td>
<td>30.2</td>
</tr>
</tbody>
</table>

Table 5.3.2. Satellite set-top box power consumption figures

http://www.ricability-digitaltv.org.uk/
Looking at the satellite STB figures in Table 5.3.2 it is apparent that both in 2005 and today the satellite set-top boxes generally use much more power than the DTT equivalents.

The consumption while operating is slightly higher than DTT, possibly due to the additional power required by the Low Noise Block (LNB) that down-converts the 10-12 GHz signal from the dish to a frequency suitable for transmission to the set top box over coaxial cable. An Astra LNB is powered from the set top box with a switchable bias of 13V or 18V to select the required polarization; current consumption is typically around 220 mA at the present time, so the arrangement can easily take 3-4W when operating. It may be possible to reduce this significantly with newer technology and more sophisticated power management.

Secondary sets and DVRs do not usually get to share a single output LNB with the primary set, as they may require different permutations of polarization and high/low band. Therefore, homes with multiple appliances will normally require a multiple output LNB.

What is particularly apparent from the Scientific Generics and Ricability measurements is that the power consumption does not drop very much in standby. This ought not to be a fundamental limitation and indeed Ricability did review one new Freesat unit (Humax FOXSAT – HD/GB) with a standby power consumption of less than 1W and overall consumption better than most DTT boxes.

We might expect that with appropriate incentives, satellite set top box manufacturers will substantially catch up with the standby power consumption performance of DTT boxes. In 2007 the commercial satellite broadcaster Sky pledged to introduce an ‘Auto Standby’ mode into all its new set-top boxes[^57] and reduce the standby power consumption to a maximum of 3W by 2010. So whilst the performance of satellite set top boxes has historically lagged that of DTT equipment, this may be resolved in due course.

Many DTT consumers will not elect to use a set-top box with an analogue television, however, but choose an integrated digital television (iDTV) instead. Table 5.3.3 shows some power consumption figures for these from Ricability. We note that there is very little difference between the ECO mode power consumption and full standby: we also note that the operating power consumption is strongly dependent on the screen size.

What is particularly interesting about these figures is that the iDTV standby/ECO power consumption is less than 1W on average, which is better than the set-top boxes in Table 5.3.1. This may because the standby power consumption of televisions has been particularly high profile in the last few years, and that manufacturers have invested more development in reducing it. Whatever the reason, there is no fundamental reason why a DTT set-top box should not have a similarly low standby consumption.

[^57]: The Bigger Picture Review 2007’ *environment section*, BSkyB
<table>
<thead>
<tr>
<th>Source</th>
<th>Operating power consumption (W)</th>
<th>ECO power consumption (W)</th>
<th>Standby power consumption (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricability November 2008 (Average of 7 off 19&quot; units reviewed)</td>
<td>44.91</td>
<td>0.94</td>
<td>0.94</td>
</tr>
<tr>
<td>Ricability November 2008 (Average of 6 off 20&quot; units reviewed)</td>
<td>53.6</td>
<td>0.97</td>
<td>0.96</td>
</tr>
<tr>
<td>Ricability November 2008 (Average of 15 off 26&quot; units reviewed)</td>
<td>93.12</td>
<td>0.91</td>
<td>0.92</td>
</tr>
<tr>
<td>Ricability November 2008 (Average of 25 off 32&quot; units reviewed)</td>
<td>124.23</td>
<td>0.74</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Table 5.3.3. DTT iDTV power consumption figures

To date there are relatively few iDTVs for UK satellite use although if Freesat succeeds we may expect this to change. Again there is no technology reason for satellite equipment to use much more power than DTT equipment.

Tables 5.3.4 and 5.3.5 illustrate some data on digital video recorder power consumption. Typically these units record to an internal hard disk drive and/or recordable DVD. It is noticeable that the standby power consumption of these units is poor compared with set-top boxes and iDTVs. Again the satellite case lags the DTT case although there is no fundamental technical reason why this should be.

<table>
<thead>
<tr>
<th>Source</th>
<th>Operating power consumption (W)</th>
<th>Standby power consumption (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Generics report 2005, Table 3, Average Value</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>Ricability November 2008 (Average of 25 units reviewed)</td>
<td>18.8</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 5.3.4. DTT digital video recorder power consumption figures

<table>
<thead>
<tr>
<th>Source</th>
<th>Operating power consumption (W)</th>
<th>Standby power consumption (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricability November 2008 (Average of 2 units reviewed)</td>
<td>30.6</td>
<td>15.9</td>
</tr>
</tbody>
</table>

Table 5.3.5. Satellite digital video recorder power consumption figures

As a reference point on volumes, DTI/DCMS in their 2005 report estimated a total of 65 million television sets in the UK. The 2005 Scientific Generics report on cost and power implications of
digital switchover came up with some slightly different figures: 24.8 million primary sets, 24.3 million regularly used secondary sets and 30 million recording devices.

Over time, we might reasonably expect many DTT set-top boxes to be displaced by iDTVs and dual-tuner DVRs as DTT reception becomes a standard feature of any television appliance. It is less certain that the satellite set-top boxes will be subsumed in a similar way, as this has not happened so far over the many years that Sky has been operating.

One counter-pressure on the integration of set top-boxes into the television is the ongoing churn in TV standards and services: many current owners of iDTVs will be adding external set-top boxes to obtain High Definition (HD) services now becoming available. Some new Pay-TV and interactive television services will also require external equipment. Left to the market, it is likely that such churn will continue as companies attempt to find new business models and commercial opportunities in the television space.

There are clearly a large number of uncertainties in the volumes of user equipment and how the mix will evolve over time: to perform an accurate assessment of the relative power consumption of DTT and satellite would require a detailed market/consumer trends survey.

However, for the purposes of this case study we will postulate a simplified scenario loosely based on the Scientific Generics figures: 25 million ‘typical’ homes each with a 26” iDTV, a 21” CRT based secondary set and an average of 1.2 digital video recorders.

Tables 5.3.6 and 5.3.7 show the corresponding results for the DTT and satellite data. The power consumption figures are based on the Ricability data with the exception of the CRT set, where the power consumption is based on a typical 2005 Philips CRT set.

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Active power (W)</th>
<th>Standby Power (W)</th>
<th>Activity per day (hrs)</th>
<th>Yearly consumption (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26” iDTV primary set</td>
<td>1</td>
<td>93</td>
<td>1</td>
<td>4</td>
<td>143.2</td>
</tr>
<tr>
<td>DTT digital video recorder</td>
<td>1.2</td>
<td>18.8</td>
<td>9</td>
<td>2</td>
<td>103.3</td>
</tr>
<tr>
<td>21” CRT secondary set</td>
<td>1</td>
<td>50</td>
<td>3</td>
<td>3</td>
<td>77.8</td>
</tr>
<tr>
<td>DTT set-top box for secondary set</td>
<td>1</td>
<td>6.4</td>
<td>4.6</td>
<td>3</td>
<td>42.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>366.5</td>
</tr>
</tbody>
</table>
Total for 25m such households: 9163 GWh/year

Table 5.3.6. User equipment power consumption estimate for DTT

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Active power (W)</th>
<th>Standby Power (W)</th>
<th>Activity per day (hrs)</th>
<th>Yearly consumption (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26” iDTV primary set</td>
<td>1</td>
<td>93</td>
<td>1</td>
<td>4</td>
<td>143.2</td>
</tr>
<tr>
<td>Satellite box for primary set</td>
<td>1</td>
<td>11.9</td>
<td>11.2</td>
<td>4</td>
<td>99.2</td>
</tr>
<tr>
<td>Satellite digital video recorder</td>
<td>1.2</td>
<td>30.6</td>
<td>15.9</td>
<td>2</td>
<td>180.1</td>
</tr>
<tr>
<td>21” CRT secondary set</td>
<td>1</td>
<td>50</td>
<td>3</td>
<td>3</td>
<td>77.8</td>
</tr>
<tr>
<td>Satellite box for secondary set</td>
<td>1</td>
<td>11.9</td>
<td>11.2</td>
<td>3</td>
<td>98.9</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>599.3</td>
</tr>
</tbody>
</table>
Total for 25m such households: 14982 GWh/year

Table 5.3.7. User equipment power consumption estimate for satellite
Currently we see that a satellite-based household uses significantly more power (63% more), mainly due to the very high standby power consumption of the satellite equipment. However as noted we may expect satellite receiver consumption to reduce significantly in the future (see below).

We also observe that the 9163 GWh/year figure for 25 million DTT households is quite a high figure, being about 2.3% of the total 2007 UK electricity production or about 8% of the 2007 UK domestic electricity consumption.

For comparison, Defra MTP estimated the UK energy consumption of televisions, digital TV adapters and video recording equipment as 13,900 GWh in 2005. The order of magnitude of this is similar to the estimates above.

Table 5.3.8 and 5.3.9 show some revised estimates based on readily foreseeable reductions in power consumption. Essentially this is the replacement of the secondary set with a small iDTV and a reduction in standby power of all appliances to 1W. It seems likely that the operating power of the satellite boxes and DVRs could be reduced also, but this has not been factored in.

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Active power (W)</th>
<th>Standby Power (W)</th>
<th>Activity per day (hrs)</th>
<th>Yearly consumption (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26” iDTV primary set</td>
<td>1</td>
<td>93</td>
<td>1</td>
<td>4</td>
<td>143.2</td>
</tr>
<tr>
<td>DTT digital video recorder</td>
<td>1.2</td>
<td>18.8</td>
<td>1</td>
<td>2</td>
<td>26.1</td>
</tr>
<tr>
<td>20” iDTV secondary set</td>
<td>1</td>
<td>54</td>
<td>1</td>
<td>3</td>
<td>66.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>236.1</td>
</tr>
</tbody>
</table>

Total for 25m such households: 5904 GWh/year

Table 5.3.8. Reduced user equipment power consumption estimate for DTT

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Active power (W)</th>
<th>Standby Power (W)</th>
<th>Activity per day (hrs)</th>
<th>Yearly consumption (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26” iDTV primary set</td>
<td>1</td>
<td>93</td>
<td>1</td>
<td>4</td>
<td>143.2</td>
</tr>
<tr>
<td>Satellite box for primary set</td>
<td>1</td>
<td>16.2</td>
<td>1</td>
<td>4</td>
<td>31.0</td>
</tr>
<tr>
<td>Satellite digital video recorder</td>
<td>1.2</td>
<td>30.6</td>
<td>1</td>
<td>2</td>
<td>36.5</td>
</tr>
<tr>
<td>20” iDTV secondary set</td>
<td>1</td>
<td>50</td>
<td>1</td>
<td>3</td>
<td>62.5</td>
</tr>
<tr>
<td>Satellite box for secondary set</td>
<td>1</td>
<td>16.2</td>
<td>1</td>
<td>3</td>
<td>25.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>298.5</td>
</tr>
</tbody>
</table>

Total for 25m such households: 7462 GWh/year

Table 5.3.9. Reduced user equipment power consumption estimate for satellite


The DTT consumption has been cut by approximately a third, and the satellite consumption is now only 26% (or 1558 GWh/year) more than the DTT case. The power consumption in these reduced estimates is now very much dominated by the operating power.

5.3.4.2 Efforts to reduce consumer equipment power consumption

At present, efforts to reduce the power consumption of television equipment in the home are mainly voluntary, although various groups have been campaigning to apply pressure. An example is the International Energy Agency (IEA) has been campaigning since 1999 to highlight the issue of standby power and has promoted its “1 Watt Plan” for all appliances (with few exemptions) to use a maximum of 1 Watt in standby mode. Even last-generation CRT televisions did not usually achieve this, but the fact that most new iDTVs do is testament to the fact that manufacturers are susceptible to such pressure. And as noted BSkyB is actively addressing the issue of standby power consumption and is taking steps to reduce it.

The EC has issued a Code of Conduct\(^6^0\) that recommends limits for operating and standby power consumption of some digital television equipment for units covered. For example DTT, cable and IP set top boxes should use less than 2W in standby and 7W operating, whilst satellite boxes are allowed 2W standby but 10W operating. However, at this point in time compliance with the Code of Conduct is voluntary.

The EC has also issued the ‘Eco-design of Energy-using Products (EuP)’ Directive. This does not directly set binding requirements on specific products, but defines criteria and conditions for doing so. Within this framework the EC commissioned a study to evaluate the environmental impacts of television equipment pursuant to the EuP Directive\(^6^1\). This develops (amongst other items) a number of proposals for eco-labelling of televisions and reviews a number of techniques that can be (and in some case are already being) applied to reduce television power consumption (ref. Task 6 of the Fraunhofer report).

Should the pace of change be deemed too slow, there is of course the option of introducing mandatory power consumption limits via government or EU legislation. A full statistical study backed by current market research would be needed to quantify accurately the potential gains which might be made by introducing better energy saving equipment: however the highly simplified model in this case study indicates that there may be a case to answer.

5.3.5 Network power consumption

DTT service was launched in the UK by means of a limited deployment of low-power DVB-T signals using spare frequencies in the analogue network: these are provided from just 81 DTT transmitter sites.

On completion of the digital switchover process, in current plans the 81 DTT sites will all operate at considerably higher power levels and (usually) broadcast 3 PSB multiplexes (MUXs) plus 3 commercial MUXs. Meanwhile the remaining 1070 transmitter sites plus a few new relay stations will transmit the 3 PSB MUXs only at power levels typically -7 dB down on the previous analogue per-channel level used at those sites.

The total ERP from 1151 analogue sites (based on Ofcom analogue transmitter data) is 14.98 MW per primary channel (BBC1, BBC2, ITV1, C4) whilst the total per-channel analogue ERP of just the 81 digital sites is 14.16 MW. Therefore, the remaining 1070 analogue relays do not transmit much power compared to the main sites (which transmit 94.5% of the total).


\(^6^1\) ‘EuP Preparatory Studies “Televisions” (Lot 5)’ Fraunhofer IZM et al, 6 August 2007
The planned post-switchover DTT operating levels for the 81 main digital sites are captured in an Ofcom site plan \(^{62}\). In this plan the main sites transmit 10,443 kW ERP for the 3 PSB MUXs, and 7261 kW for the 3 commercial MUXs. The other 1070 former analogue transmitter sites will transmit a further 491 kW ERP approximately for the 3 PSB MUXs (based on the \(-7\) dB relative to analogue figure). Therefore, about 95.6\% of the total PSB ERP post-switchover is transmitted from the 81 main sites, a situation similar to the analogue system; and about 97.3\% of the total (PSB plus commercial) ERP is from the main sites.

Adding the above figures together we estimate the post-switchover DTT network total ERP as \(18.2\) MW \(^{62}\). Working backwards from this total network ERP figure, we can estimate the approximate power consumption required for the DTT network, as shown in Table 5.3.10.

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total network ERP</td>
<td>(P_{\text{ERP}})</td>
<td>18.2</td>
<td>MW</td>
</tr>
<tr>
<td>Mean antenna gain</td>
<td>(G)</td>
<td>10</td>
<td>dB</td>
</tr>
<tr>
<td>Total RF power transmitted by Network (\text{[} \frac{P_{\text{ERP}}}{10^{G/10}} \text{]})</td>
<td>(P_{\text{TOT}})</td>
<td>1.82</td>
<td>MW</td>
</tr>
<tr>
<td>Mean transmitter efficiency (including feeder losses)</td>
<td>(\eta)</td>
<td>14</td>
<td>%</td>
</tr>
<tr>
<td>Estimated DC power consumption (\text{[} \frac{P_{\text{TOT}}}{\eta} \text{]})</td>
<td>(P_{\text{DC}})</td>
<td>13</td>
<td>MW</td>
</tr>
<tr>
<td>Energy consumption per annum (\text{[} P_{\text{DC}} \times 24 \times 365.25 \text{]})</td>
<td>(E_{\text{PA}})</td>
<td>114(^{63})</td>
<td>GWh/year</td>
</tr>
</tbody>
</table>

Table 5.3.10. Estimated post-switchover DTT power consumption

(Note: this analysis considers the power consumption of the distribution network to be outside the system scope).

Operating a DTT transmitter network clearly incurs a significant amount of power consumption. However, to put this in perspective, this is about 0.03\% of UK electricity generation for 2007, and only about 2\% of the domestic television equipment power consumption estimated in Table 5.3.8.

It is readily apparent that a satellite broadcast system does not require much terrestrial infrastructure to provide the uplinks, at least as compared to a terrestrial TV network. However appropriate system architecture and power consumption data for uplink facilities is difficult to obtain so that estimates might be made. Also of issue is what proportion of the total uplink facilities to include, in terms of their direct contribution to the TV transmission, as compared to their support for the satellite for (likely) other, unrelated, services, and for station keeping functions etc. However, on the basis that only one or two uplink facilities are needed in practice, and that we

\(^{62}\) ‘Digital Switchover Transmitter Details: Existing 81-Site Plan’ issue 2.0, Ofcom, 24 October 2007

\(^{63}\) This is higher than the 53 GWh/year figure presented in the 2005 DTI/DCMS report, primarily because the transmission level for all the PSB MUXs and many of the commercial MUXs (particularly at the larger sites) has been increased from \(-10\) dB to \(-7\) dB relative to analogue. Additionally, we consider the TDN power consumption estimate for commercial channels in the DTI/DCMS report somewhat low relative to the PSB figure, however the TDN/Ofcom primary source calculation could not be verified.
have already determined that infrastructure energy consumption is a smaller contributor than the consumer equipment, we shall assume that the uplink power consumption is proportionately small and may be set aside for the purpose of the current discussion.

Overall we thus have to conclude that the operating power for the terrestrial transmitter network should not be a primary target for energy efficiency as it is small (approximately 2%) compared to the estimated national power consumption of user television equipment; and further that this is not likely to be a compelling reason to, for example, phase out DTT in favour of increased satellite broadcasting.

5.3.6 Manufacturing, installation and disposal

5.3.6.1 User Equipment impacts and beginning and end of the life cycle

Given the large volumes of consumer electronic equipment required to obtain service from either DTT or satellite systems, an important concern is the environmental impact of manufacturing, installation and disposal of such equipment.

In a steady-state condition, the quantities and nature of consumer ‘boxes’ in the home are not likely to depend significantly on whether the service is obtained by DTT or satellite. Some differences which may exist are that for satellite there may be a slightly greater quantity of equipment needed arising from LNBs (perhaps multiple) and provision for second sets (more cabling and higher penetration of set-top boxes). Otherwise the quantities and complexity of the equipment needed are quite similar.

The ‘carbon footprint’ in the manufacturing of this equipment might however be expected to vary quite widely depending on the source of power, materials used, location of manufacture, transportation method and carbon offsetting policy of the manufacturer. Evaluating these aspects and finding ways to incentivise manufacturers to improve matters is still very much a developing area.

Similarly, the disposal method and degree of recycling will also affect the environmental impact. Within the EU, the WEEE directive puts in place a framework whereby electronic waste is separated and can potentially allow reclamation of some material: metals and bulk plastics for reuse as fillers, for example.

Where these impacts become of particular concern to the DTT versus satellite study is when we consider a non steady-state scenario. In the days of four-channel public service analogue broadcasting only a television could be a quite long-lived piece of equipment, being retained for years or even decades. (In many households, when a primary set was replaced it would continue to serve several years as a secondary set). The advent of multiple channel digital TV and multiple service providers will potentially increase equipment churn as follows, due to the following two mechanisms:

- The more rapid evolution of digital TV technology creates a competitive landscape in which equipment manufacturers can regularly offer ‘better’ equipment: such as HD broadcasting, interpolating DVD units, units with more storage and video-on-demand capability.
- Many consumers will switch regularly between providers every few months or years in response to service differentiation offered by these providers, or simply to benefit from temporary ‘deals’. When they do this they will often elect to ‘upgrade’ set top boxes if (as usual) the cost of these is bundled in with the deal.

These factors affect the average equipment lifetime, and thereby the environmental impact of the equipment. Accurate life cycle assessment (LCA) is complex, time-consuming and expensive, however some data is becoming available on certain classes of product. As noted previously, a
recent development is the EuP (Energy-using Products) Directive from the EC that aims amongst other objectives to improve the overall environmental performance of consumer products and thereby protect the environment. As part of this, the EC has commissioned a number of preparatory studies into the eco-design of such products including one for television equipment, which is a useful source material for this discussion.

The EuP Fraunhofer study includes a life cycle impact assessment for a number of base cases, including a 32” LCD television. A summary is reproduced from the EuP report in Figure 5.3.1.

Figure 5.3.1. Life cycle impact assessment for 32” LCD TV

This analysis only applies to one popular type of television, and is well caveoted in the EuP report. Nevertheless we may draw some interesting conclusions from this data.
In terms of Gross Energy Requirements (GER), approximately 86% is due to electricity consumed in the use phase. This is based on a 10-year primary use lifetime and 4 hours activity per day.

(Note that the GER metric includes generation and transmission inefficiencies and is therefore almost three times higher than the device electricity consumption).

The lifetime greenhouse gases are 1.3 tonnes of CO₂ equivalent and again almost all of this (84%) is incurred during the use-phase.

At End-of-Life, approximately 6.3 kg of materials are disposed of and 16.8 kg of materials are recyclable.

Significant amounts of additional waste (56.3 kg total) are produced during the life cycle, mainly during the manufacturing and use phases. (We assume that the 29.2 kg use phase waste is associated primarily with power generation though this assumption is not documented in the EuP report).

Numerous other emissions and impacts have also been quantified.

In terms of energy usage and greenhouse gases, power consumed during the usage phase account for most of the environmental impact. Manufacturing, distribution and disposal/recycling would appear to much less significant contributors. However we should note the following:

- A 10-year primary use lifetime is quite a long time, and this may reduce significantly in future. Task 3 of the EuP Fraunhofer report discusses this in more detail and suggests that for the future an assumption of 8 years primary use would be more appropriate.

- This study only addresses the television itself. It seems probable that the turnover of set-top boxes will be higher, especially if the commercial pressures discussed previously apply.

If found to be a problem there may be technological ways of increasing the average appliance lifetime such as creating standards for software based, upgradeable or more modular set-top boxes. This may not be impractical given that manufacturers and service providers alike are continually striving for competitive advantage by coming up where possible with unanticipated technology innovations.

We should also consider the installation impact. Satellite typically a disadvantage here in that addition of new services, and from time to time of extra sets, can for many consumers require a technician to make a dedicated journey with associated fuel costs and impacts. DTT on the other hand, is in principle much more amenable to self-installation by the householder - although in the pre-switchover transition period a significant number of householders do need to use an aerial installer to upgrade their yagi antenna and/or down lead. Travel by users to purchase DTT equipment can also be factor, but the impact depends on the proportion of journeys that are considered to be solely to buy DTT equipment (as compared to journeys the user would have made anyway).

To put this in perspective, if a diesel van producing 274 g/km of CO₂ has to do a 120 km round trip to install a dish, the 32.9 kg of CO₂ produced is equivalent to about 58.5 kWh of electricity production. Looking at the operating power estimates in Section 5.3.4.1 this is less than 3 month’s consumption for one subscriber, even using the best case figures from Table 5.3.9.

We thus conclude that in-use power consumption appears to be the dominant energy and CO₂ impact for televisions, and that the other life cycle impacts are much less significant. The manufacturing and disposal of set top boxes and other television appliances may however merit further investigation.
5.3.6.2 Network life cycle impact

The large network of DTT transmitters and rather smaller network of satellite uplink stations also have a potential environmental impact due to manufacturing, installation and disposal. This impact would require a detailed LCA to quantify, although as this infrastructure typically has a twenty-year life cycle and serves a very large number of consumers, it may not be all that significant. Furthermore, the masts and cabling may well have an even longer life.

Likewise the satellites for a satellite system will have a manufacturing impact and also a disposal impact, as disposal is commonly by de-orbiting at the end of life. Despite the exotic nature of the technology used, the satellites themselves are only a few tonnes each so it seems unlikely that these impacts are large compared with the hundreds of thousands of tonnes of consumer equipment bought and disposed of during their (long) lifetime.

Another possible environmental impact for satellite is that of the launch. The ‘High Tech: Low Carbon’ Intellect report\textsuperscript{64} suggests that a satellite launch releases less CO\textsubscript{2} than a single transatlantic passenger flight, and the material lost in the launch is about 10\% of a single aircraft by mass. It also claims a typical satellite lifetime of 20 years so again we might expect the impacts of a launch to be minor compared to the operating power and manufacturing/disposal of hundreds of thousands of tonnes of user equipment over that time.

5.3.7 Distribution network

We have made a simplifying assumption consistent with ‘top down’ system/subsystem analysis and assume that the distribution network providing the TV content to the transmitter sites has similar environmental impact in both DTT and satellite cases.

Some justification for this is that most of the analogue transmitter sites today (approximately 1100) act as relays for the 51 main analogue transmitters: i.e. they receive the signals from the main site, perform a frequency conversion and rebroadcast on a different frequency. Therefore, there are only of the order of 51 transmitters to distribute content to. For the full DTT system after switchover, it is likely that a similar approach will be followed although most of the relay sites will only retransmit the three PSB multiplexes.

Today, a number of methods are used to distribute television to the analogue transmitters: fibre optic links, microwave line-of-sight radio systems and (increasingly) satellite feeds. In principle the whole task could probably be performed by satellite in which case the terrestrial distribution network could be approximately equivalent in environmental impact to the satellite broadcast uplink network.

The assumption that we can disregard the distribution network therefore may or may not be valid and merits further work to determine how multi-channel content gets from the content companies to the DTT and satellite transmitter locations. It would then be possible to determine whether there is a case to answer on the environmental impact of this network segment.

5.3.8 Visual impact

Two aspects are of interest here: the visual impact of the network infrastructure, and that of the antennas used by the consumer.

5.3.8.1 Network infrastructure

Satellite systems require a relatively small number of uplink stations that may be sited on an industrial estate or science park. In contrast, the DTT system requires a large number (at least 1154

\textsuperscript{64} ‘High Tech: Low Carbon: The role of technology in tackling climate change’, Intellect, February 2008
under the current plans) of tall masts stationed (where possible) on high ground. These tend to be very conspicuous.

Most people would agree that the DTT system has a much higher environmental impact in visual terms. It is difficult to weigh this visual impact in a meaningful way against the benefits of the DTT system. Whilst there might well be an outcry if 1154 new masts were introduced onto greenfield sites today, the UK public have been living with analogue TV masts for over 60 years and are well used to the benefits.

A carefully constructed public survey might be able to produce some practical conclusions in some situations (for example: would consumers in a National Park be willing to trade their DTT service for Freesat in order to lose a conspicuous mast?). Trying to weigh the visual impacts into an overall UK TV evolution strategy on a larger scale may however be impractical.

An additional point worth considering is that masts are needed for other radio systems and most TV transmitters share their masts with a plethora of other systems. Therefore, even if DTT were to be dramatically reduced or phased out it is far from certain how many masts could be dismantled.

5.3.8.2 Consumer antennas

For most consumers at present, DTT service requires a UHF yagi antenna at rooftop and the regulations permit this to be on a mast standing above chimney height. Given the low power partial deployment of DTT at present many consumers are in marginal reception areas and have had to install high-gain yagi antennas on tall masts which are more conspicuous that their old analogue antenna.

In contrast, satellite dishes are not permitted to be positioned above chimney height. Astrium expressed a view that satellite dish antennas have no more visual impact than the DTT yagis, and as they can often be situated well below roof height (or even on the ground) the impact is often less.

Once the full scale, full power DTT system has been deployed the situation may change in that fewer people will need tall masts and very high gain antennas to receive service. It is also possible that some people will be able to use loft antennas or even small set-top antennas within the house and eliminate the external yagi entirely. In this case, the visual impact of DTT antennas may be substantially a legacy of the digital switchover transition that will resolve itself in the fullness of time.

Ultimately, whether a yagi is more beautiful than a satellite dish is in the eye of the beholder. As for the case of terrestrial TV transmitter masts it may be the case that the public is so used to living with rooftop UHF TV antennas that they are considered more acceptable than the newer dish antennas; irrespective of any absolute aesthetic considerations.

5.3.9 Use of spectrum

Spectrum usage is not normally considered an environmental issue, but it is possible that a radical change in the DTT deployment may have environmental consequences due to this factor.

DTT uses a range of frequencies between 470 MHz and 860 MHz whilst UK satellite TV uses frequencies between 10-12 GHz. The digital switchover is releasing at least 14 UHF channels within the 470-860 MHz terrestrial range, which will then be available for other uses. This spectrum is well suited to a wide range of mobile communication applications, due to its low frequency and advantageous propagation characteristics. By contrast, the 10-12 GHz satellite band is really only suitable for fixed or nomadic line-of-sight communication links. The DTT spectrum is therefore much more valuable in market terms.

It remains to be seen what the 14-channel ‘digital dividend’ spectrum liberated by digital switchover will be used for. However, it seems possible that many of the new services may have
higher environmental impact than terrestrial TV broadcasting. For instance, one likely candidate would be terrestrial mobile-broadband networks (such as WiMAX or LTE) which can require dense networks of short-range base stations, highly linear (and relatively inefficient) power amplifiers and a high capacity broadband core network. Another possibility is an expansion of the existing 2.5G/3G cellular networks that also exhibit considerable environmental impact.

The digital dividend may be a fait accompli for switchover, but changing the mix of DTT and satellite could further affect the amount of 470-860 MHz spectrum released for other services in the longer term. For example, if the usage of DTT naturally declines over time in favour of satellite distribution (whether encouraged by policy or not), it may become possible to reduce the number of frequency channels required and yield a further ‘digital dividend’. To take the extreme, if the DTT service were to be withdrawn completely, this would potentially save the operating power consumption of the terrestrial network, but may then be substituted with the consumption of 400 MHz or more of cellular and broadband systems.

The introduction of digital TV thus provides a good example of the generic issue of spectrum usage. DTT brings benefits compared to the previous analogue transmission system, as a result of advances in technology such as efficient modulation schemes and advanced compression techniques. The result is more channels transmitted in significantly less spectrum, with less network energy consumption compared to analogue. Paradoxically, however, this makes it possible to operate more systems in the same amount of spectrum and thereby possibly increases environmental impacts in the future.

5.3.10 Service impacts

One of the difficulties with any environmental assessment is how to weigh an environmental benefit against service and society benefits. When considering the environmental impact of satellite TV versus DTT, we have to ask the question whether the consumer is getting a completely comparable service in either case.

5.3.10.1 Service equivalence

As noted in the case study Introduction, the services offered by satellite and DTT are almost equivalent at this point in time. One major difference that does exist is that satellite television in the UK (from Sky) has historically been subscription-only, without any ‘free-to-air’ public service broadcasting on offer. This has changed recently with the advent of Freesat although subscription Sky TV still has the dominant market share.

By contrast, DTT operates today as a substantially free-to-air service (Freeview). The UK DTT system does have a few pay-TV channels available, but lacks the same range of premium content offered by Sky.

The absence of much pay-TV on DTT is more due to commercial and historical factors than technical limitations. This may have changed significantly by the time of digital switchover: indeed Sky and Arqiva are in discussions with Ofcom at present concerning a proposal to add five pay TV channels to the DTT system. However, those households requiring a wide choice of premium content (such as subscription based sport and films) may be obliged to continue using satellite service from Sky unless they live in an urban area served by CATV or IPTV.

5.3.10.2 Coverage

Following completion of digital switchover (DSO) Ofcom is aiming to ensure that at least 98.5% of

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UK households can receive the Public Service Broadcast (PSB) channels using the DTT network. (As of May 2007, these channels were BBC One, BBC Two, ITV1, Channel 4, Five, CBeebies and CBBC). The target of 98.5% was determined to match the estimated coverage of PSB analogue in 2005.

Ofcom plans to achieve this coverage by placing obligations on the holders of Digital Replacement Licences (DRLs) to convert a certain minimum number of transmitter sites to digital.

The planning continues to change and evolve in the details. However as of December 2006 Ofcom’s position was that to achieve the 98.5% figure, DRL holders would be obliged to convert all 1154 analogue transmitter sites to transmit the three PSB multiplexes, and would likely be required to add about 9 additional transmission relays. No such obligation would be imposed on the remaining three commercial multiplexes, other than that DRL holders should continue to maintain at least the then current level of 6-multiplex coverage (estimated as 73% from 80 transmitter sites).

For comparison, Freesat and Sky achieve about 98% UK coverage (the figure claimed by Sky on their website; Freesat shares a common space platform with Sky and therefore has the same coverage).

Where does this leave us with coverage? In the current plans, DTT will provide:

- Approximately the same (and very high) level of PSB coverage as satellite
- A rather lower level (possibly as low as 73%) of full six-multiplex free-to-air coverage than available from Freesat, unless the DRL holders make the commercial decision to increase the coverage by upgrading more transmitter sites.

Therefore, to provide truly equivalent service to Freesat over >98% coverage, a larger DTT deployment would be required than in the current plans. This is unlikely to happen however, as the DRL holders have informed Ofcom that a wider six-multiplex deployment is not commercially viable.

With regard to indoor coverage and second sets in a household, it is currently possible in certain circumstances (within areas of good coverage) for second TV sets (i.e. TV sets other than the primary set) to obtain acceptable DTT service using small indoor set-top antennas. However this is very dependent upon the location of a set within a given property. This may be expected to improve somewhat following switchover when the transmission levels of the main network are increased.

Whilst the use of a loft/roof antenna is the normal installation requirement for DTT, the ability for set-top antennas to be used in certain situations (as for analogue terrestrial) is in an additional advantage over satellite. Satellite requires an external high gain antenna for adequate link budget, requiring distribution of signals within the home to cater for multiple TV sets.

5.3.10.3 Mobility

One potential point of difference between DTT and satellite is that of mobility. The DTT DVB-T network can potentially support mobile TV broadcasting as well as domestic service using the DVB-H standard. DVB was originally designed to support both standards within one multiplex. In contrast, due to the much higher frequency of operation and high gain antenna requirement, mobile TV is not a service that can be offered directly by a satellite system today.

In practice it is unlikely that the DTT network will be suited to fully supporting DVB-H deployment in the UK. Despite the additional link budget available from the DVB-H system, the
requirement for good indoor coverage on a mobile platform in urban areas requires a much higher density of transmitters than the UK DTT network can provide. A useful DVB-H network will therefore require a large number of small transmitters to be overlaid (at mobile cell sites for example).

5.3.11 Conclusions on Digital TV

We return to our first question: what are the relative environmental impacts of DTT versus satellite TV distribution and is one better in this respect than the other?

This case study is necessarily constrained in scope and a full environmental assessment would require a great deal more research and analysis. However we can tentatively conclude the following.

Operating power consumption is dominated by power consumption of the user equipment. Whilst the power consumption of the DTT transmitter network is an additional impact that a satellite system does not suffer, its impact is a relatively small proportion of the overall system.

At this point in time, satellite user equipment does consume significantly more power than the DTT equivalents. However, this difference can be reduced to quite a small factor by foreseeable refinement of the equipment. Some of this refinement is happening naturally, and it could be ‘encouraged’ further by labelling initiatives or regulatory legislation.

Adopting a 1W standby requirement for domestic television equipment and possibly providing an incentive for reduction in operating power, looks to be the best single opportunity for reducing overall electricity consumption. This applies to both types of system.

Regarding manufacturing, installation and disposal, it is evident that for the DTT transmitter network, the long life cycle (operational life) and the large number of consumers served will amortize these environmental impacts to a relatively low level compared with the impacts of user equipment (a detailed life cycle analysis of both would be required to help confirm this). Satellite life cycle and launching impacts also do not look to be a major concern, again due to the long operational life of the satellite.

For the user equipment, the manufacturing and disposal of televisions themselves looks to be a relatively lesser problem compared with the in-use power consumption. Set-top boxes and DVRs may be more of a concern, especially if such equipment migrates to a shorter usage cycle than a traditional domestic primary set.

Such impacts apply to both DTT and satellite systems, though they may be exacerbated by customer churn caused by competition between them.

Whilst the DTT transmitter system does have some disadvantages in terms of visual impact and land use, the public is well used to living with these. A carefully constructed public survey would be needed to see whether people would support a switch to satellite in order to remove transmitter masts. Even if the answer were yes, it is questionable how many masts could actually be removed as in many cases they are not used just for television. The visual impact of a yagi antenna versus a dish is another topic which would require market research to determine user views.

With regard to the second question, of whether the multiple methods of delivery are in themselves causing excessive environmental impact, we have concluded that network-side environmental impacts are low compared to the user-side impacts. Thus in a static scenario there would not seem to be strong effect of technology choice on the overall impact.

Given that DTT and satellite consumer equipment (and indeed cable equipment) tend to displace each other in the marketplace, we conclude that having multiple TV delivery methods does not lead to substantial increases in environmental impacts.
A possible flaw in this argument is that alternative providers of services, as they compete in the market place, will generate churn of equipment as they pull consumers back and forth between each other. If the equipment is broadly similar in capabilities and technology (as should be achievable in the long run) this may not make much difference to operating power consumption but it will increase the environmental impact due to manufacturing, installation and disposal. Set-top boxes in particular will be hard to eliminate if service providers continue to use them to roll out proprietary services in order to differentiate themselves from their competitors. HDTV is an example where a new generation of set-top boxes is being introduced to allow upgrading.

It would merit further study to quantify the manufacturing, installation and disposal impacts, and consider whether there is an ‘optimum’ number of service providers to balance environmental impact with the benefits of healthy competition.

From this case study we may thus draw the following conclusions:

- That there is probably not an overwhelming environmental advantage of one television technology over the other.
- That there are significant environmental benefits to be gained by improving the power consumption of the user equipment for both systems.
- That the environmental impact of manufacturing and disposal of user equipment (especially set top boxes) merits further study, particularly if equipment does not see a long service life.

We also conclude that even if there were a strong case for phasing out one system, it would probably not be possible to eliminate the entire DTT network in the short term, even though the predicted coverage obtained by satellite (98%) is almost as high in numerical terms as that estimated for DTT (98.5% post-switchover).

This is because the mature analogue network has created a service expectation. Whilst the numbers might be similar, the distribution of people not covered by either system is likely to be different. By its nature the DTT system after switchover should achieve very similar coverage characteristics (for PSB) to the previous analogue system. Satellite broadcasting on the other hand is prone to shadowing from large and small-scale obstacles (such as hills, buildings and wet foliage) resulting in quite different coverage characteristics.

With the legacy of analogue broadcasting, even if only a few tens of thousands of viewers were disenfranchised by a hypothetical move from DTT to satellite broadcasting, this would be seen as a major problem.

Both this and other case studies focus on power and carbon. This is appropriate as assumptions can be made that non-carbon impacts are similar for the different equipment compared and are dependent on turnover due to fashion/obsolescence (for consumers) and investment cycles (for commercial systems) that can be assumed not to differ significantly between technologies.
6 Positive (indirect) impacts

Communications technologies or ICT more generally can substitute for, and, thereby avoid, the negative environmental impacts of other activities. As reflected in the studies reviewed in Appendix B, considerable work has examined the potential environmental benefits of applying communications technologies in this way. These positive environmental impacts arise through the second and third order effects of communications.

Section 2.2 introduced how 1st order impacts relate to the direct (and almost always negative) environmental impacts of manufacture, operation, disposal etc; 2nd order effects are indirect environmental effects of ICT that arise as processes change, such as different energy management processes; 3rd order environmental effects arise due to collective medium or longer-term adaptation of behaviour (e.g. travel patterns), due to the stable availability of communications technology and the services it provides.

This section summarises a range of evidence on teleworking, teleconferencing, and other positive 2nd and 3rd order effects. Teleconferencing differs from teleworking in that it refers to using ICT to substitute for business travel rather than for commuting. It includes undertaking meetings via group phone calls (teleconferencing) and video-links (video-conferencing). The studies referred to are reviewed in Appendix C.

The interaction between 1st, 2nd and 3rd order effects can be complex, and there can also be ‘rebound’ (particularly for 3rd order) negative environmental effects – for example those that arise as more efficient systems give people more free time, and therefore stimulate increased leisure travel. Analysis of 2nd and 3rd order environmental benefits must consider the extent to which they should take into account both 1st order and 3rd order environment costs. 2nd order effects are generally assumed to be positive for the environment.

In a recent study Intellect, the trade association for the UK technology industry, breaks beneficial 2nd and 3rd order effects of technologies down into:

- Enhancing: making existing processes more efficient e.g. intelligent transport.
- Enabling: allowing us to do things differently e.g. the paperless office.
- Transforming: leading to alternative low-carbon business models e.g. broadband.

A key area of potential 2nd and 3rd order benefits from communications systems is in substituting for travel, either through teleworking (in which commuting is avoided) or teleconferencing (in which business travel is avoided). Data on carbon emissions from the UK’s Committee of Climate Change’s First Report (see Appendix C) illustrate the scale of the environmental impacts from transport in the UK, and the substantial variation in the relative impact of individual journeys by different modes. The major emissions impacts from travel, which communications systems can potentially substitute for, are car journeys and international aviation.

Communications might also be important in relation to emissions from HGVs and vans, by substituting for them, or assisting with logistics management (2nd order effect).

Whether these environmental impacts of travel will be reduced by substitution with communication systems depends on complex sociological and economic factors. Their accurate assessment needs to consider the nature of communications at a distance and whether and how they might in certain circumstances reduce the need for travel.

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To achieve potential reductions in environmental impacts, ‘communications’ will have to provide some of the characteristics of face-to-face interaction. These are immensely difficult effects to apply numerical analysis to, but it is clear that telecommunications can substitute for some, but not all, of the benefits of face-to-face meetings. While it may be environmentally desirable to communicate on the screen, there may be many other reasons why this is thought undesirable. Modern social networks are maintained through intermittent physical meeting, and more regular telecommunications. In this sense communications are a complement to travel.

6.1 Teleworking

Much has been made of the possibility that teleworking can substitute for, and therefore reduce, negative environmental impacts associated with commuting and business travel. Studies such as those detailed in Appendix C (e.g. Smart 2020) highlight the potential reductions in environmental impacts.

Some major companies have now implemented organisation–wide teleworking policies and cite significant benefits to their business and the environment from doing so. These are analysed in detail by Cairns (in preparation). For example, studies have found that on days they telework, employees reduce travel mileage by 48% - 77%. However this saving falls to 11% - 19% for their overall travel, indicating a rebound effect of 30% or more (DfT, 2004).

Delivering these business and environmental benefits involves a significant organisational management effort. For example, as well as implementing teleworking practices internally, BT also sells services to customers to help them implement teleworking practices. This service does not just involve installing and operating the relevant technology. It also involves providing staff training in the skills required to use the new technology effectively, such as how to organise teleconference calls, or manage remotely located teams of staff.

However, not all studies of teleworking identify net savings in environmental impacts. There are also 1st order impacts to be considered: in terms of the operation of the communications equipment (which in practice are usually of lesser significance) and its manufacture, and the buildings/facilities where it is located (e.g. extra heating and lighting at home for home workers); and 3rd order (including rebound) effects in relation to other travel activities.

Several academic studies have calculated the avoided carbon emissions from teleworking, and other studies (including others mentioned in Appendix C) originating from the communications technology sector assess potential levels of substitution of travel by teleworking. A handful of studies approach the issue of substitution between teleworking and travel from the perspective of how business activities are organised. By not taking a technology-driven perspective, they attempt to assess the actual likely levels of substitution, rather than potential levels.

The observed data within various companies demonstrate net environmental benefits in relation to their operations, but are generally limited in scope such that they do not cover 3rd order effects arising in employees’ non-work activities. An Oxford study does try to be comprehensive in this way, but its conclusion that negative 3rd order effects on the environment do not outweigh the

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68 John Urry, Distinguished Professor, Dept of Sociology, Lancaster University: personal comm.


environmental benefits from teleworking contrasts with both Aebischer & Huser’s\textsuperscript{71}, and Loerincik’s findings\textsuperscript{72}. Further investigation of the specifications of these studies may be justified to understand how the differences between their conclusions relate to the UK. However, all these studies show that 3\textsuperscript{rd} order effects are a significant influence on the net environmental impact of teleworking, and therefore that it is essential to take them into account.

6.2 Teleconferencing

Several studies have calculated the avoided carbon emissions from videoconferencing (see Appendix C). They all identify reductions in travel and therefore carbon emissions. In addition, a number of them identify emissions savings net of the impacts of running the relevant equipment, rebound effects, and generation of additional meetings. They also identify significant financial savings. However, work by TRL\textsuperscript{73} taking the perspective of examining substitution options for short-haul aviation concluded that the ‘dominant empirical result’ is of complementarity with telecommunications, not substitution. Nevertheless, their review of estimates of the extent to which business travel mileage (excluding commuting) could be reduced by telecoms identifies savings ranging between 10\% and 35\%.

A current paper by Cairns\textsuperscript{74} directly assesses the interaction between teleconferencing and business travel; specifically whether teleconferencing can reduce business travel if it is introduced to do so in a travel minimisation context. Detailed examination of the issues reveals complementarity as well as substitution, often depending on the purpose and style of the business in question, and that on an aggregate level, greater use of telecommunications does not automatically reduce travel.

Cairns reviews over a dozen studies, including the successful substitution of business travel by teleconferencing within BT. For example, studies with BT in 2000 and 2003 identify 75\% and 52\% respectively of teleconferencing substituting for face-to-face meetings, and so potentially reducing travel, (DfT 2004). However, as many forward-looking studies highlight potential for communications to reduce environmental impacts, they tend to be optimistic about the positive aspects of ICT.

The financial and behavioural determinants of whether business travel could or will be replaced by teleconferencing produce significant differences between the estimates of likely substitution. While many users report financial savings from introducing teleworking, cost barriers may exist in a perceived sense, and so pilot projects and pump-priming funding may be appropriate to overcome this. Cairns concludes that teleconferencing can be effective in reducing business travel, where it is introduced by organisations where this reduction is either an explicit or implicit aim, and is be supported by specific policies.

6.3 Discussion of 2\textsuperscript{nd} and 3\textsuperscript{rd} order indirect impacts

The analysis above shows a broad range of potential 2\textsuperscript{nd} and 3\textsuperscript{rd} order benefits from communications technologies. There is an equally broad range of context-specific factors that must be taken into account in interpreting the results of these studies or in trying to deliver potential


\textsuperscript{74} Cairns S (in preparation) ‘Can Teleconferencing reduce business travel?’. This section is based entirely on Cairns’ analysis, with some of the text drawn directly from her paper (with permission).
savings. Many of these factors (such as the costs of travel, or other activities for which communications are substituting) are drivers that may be outside of Ofcom’s influence.

As with travel studies, analysis of other types of 2nd and 3rd order effects also provides ambiguous results. For example, the impact of the Internet on energy use is controversial in the US, with one view that it accounts for 8% of electricity use and another of net savings in most sectors. Studies such as Smart 2020 have highlighted the positive 2nd order effects that ICT can bring to the management of resource consumption, for example in buildings and motorised systems. This is supported by Loerincik’s work, which examined telemonitoring of electricity, heating, water and gas networks, and found that efficiency improvements outweigh system costs.

A Swiss/German study on the future environmental impacts resulting from the spread of computing and ICT into people’s daily lives identified different positive and negative environmental impacts. Positive impacts include the increased efficiency of operating communications infrastructure and the virtualisation of services. Negative impacts include increases in volumes of data (and therefore ICT capacity and energy use) and problems of implementing new systems to achieve savings.

There is a tradeoff between next generation technologies bringing new hardware purchases and sometimes increased operating impacts, and the exploitation of networks for savings in environmental impacts (e.g. of carbon savings through e-commerce once all parties have the right technologies available).

Accurate appraisal of 2nd and 3rd order effects must look at which activities are additional and which are substitutes. Where there are substitutes, it needs to consider how any resource savings associated with the reduction in environmentally damaging activity (e.g. more time or money from less travel), are used – the rebound effects. Net environmental benefits are those that are additional and net of rebound effects.

However, assessing which activities are rebound effects is very hard and depends upon knowing about individual’s or household’s activities and internal relationships. Most travel type decisions take place within a household context and are not only or predominantly ‘individual’. Much research treats transport and communications as separate activities that people wish to undertake, but mostly people are seeking to undertake activities with others, which in turn involves travel and communications in varied combinations. This is reflected in the conclusion by Cairns that understanding of the types of business interactions involved is important to understanding substitution of business travel.

The papers reviewed in Appendix B (including Cairns) indicate a number of issues that must be taken into account in considering the potential of teleworking and/or teleconferencing to reduce the environmental impacts from travel.

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79 The process of moving from physical goods (e.g. a CD or DVD) to services without a physical existence (e.g. a music or film download).
• Which types of travel can be replaced
• Will the communication technology act as a complement to, or a substitute for, travel
• How will the communications technologies change the interactions between individuals in the long run
• What travel will be necessary to access the telecommunications facilities
• What rebound effects will there be in terms of changes to private travel behaviour
• How far should rebound effects on travel be included in the assessment of the impacts of communications technologies
• What 3rd order effects will there be, in terms of the equipment and workspace needed to operate the teleconferencing equipment.

The additionality of all these factors is complex, but needs consideration before conclusions can be drawn that communications activity is having positive 2nd or 3rd order environmental impacts. Delivering environmental benefits through communications technologies requires the right management regime to be in place around them, both in terms of the activities of users, and the goals of policy makers.

For users, uptake of communications technologies must be supported by other necessary actions (e.g., setting appropriate organisational management objectives, development of users’ skills). Importantly, the use of communications can also change working practices in an organisation, reflecting how it is a determinant of, as well as potentially a substitute for and complement to, business and travel activity.

6.4 Conclusions on positive impacts

It is evident that communications technologies are significant enablers of 2nd and particularly 3rd order indirect environmental benefits, such as reduced impacts from travel. However, there is often no absolute or clear answer with regard to the extent of 2nd and 3rd order environmental benefits that can be associated with the use of communications, or the explicit role of communications in achieving them.

The uptake of communications technologies will not inevitably lead to, or act as a driver for, reductions in environmental impacts. Wider circumstances, in particular other market-drivers, are crucial in determining net environmental impacts. These other market drivers are complex, and can give opposite influences.

If policy goals are to reduce travel, then communications technologies can help deliver this policy at reduced costs to society than otherwise. However, if there are no policy levers driving the intended beneficial environmental outcome, the availability and uptake of communications cannot be expected to deliver it. For example, current market forces, such as increased costs as a result of congestion, are driving the uptake of teleworking. Without appropriate travel management policies in place, the resulting reduction in congestion will reduce its costs and therefore may stimulate further travel. Overall the communications technologies are a necessary, but insufficient part of reducing travel and its associated impacts. This reflects the role of communications as a facilitator (and not a driver) of these changes.

Whilst Ofcom has a role to help encourage the adoption of the relevant technologies, this will only bring environmental benefits if coordinated with measures elsewhere within Government and society to encourage the other necessary components. It is noted that of the policy conclusions drawn by Cairns from her detailed study of teleconferencing’s ability to substitute for business travel, only two policy areas (publishing guidance and marketing) are currently within the remit of
Ofcom, in comparison to a number of strong drivers (such as tax incentives) that are not. This reflects the fact that if Ofcom is to promote communications as a substitute for travel in order to reduce environmental impacts, this needs to be as part of a wider policy objective shared by the rest of Government.
7 Conclusions & recommendations

We now draw together the main findings and conclusions from the previous sections and make some specific recommendations.

7.1 Impacts of systems

Much work has been and is being done to assess the impact of ICT systems as a whole and on a global basis, but studies and data relating specifically to communication systems are more limited. There is basic agreement on the broad ICT picture, with the total global carbon footprint currently being of the order of 800 MtCO₂e (megatonnes carbon dioxide equivalent) or approximately 2% of global emissions. This is predicted to grow to around 1,400 MtCO₂e by 2020, or approximately 2.8% of global emissions at that date.

Of this, contributions from global telecommunication systems - mobile, fixed and communications devices but excluding TVs & TV peripherals - currently approach 29% or approximately 230 MtCO₂e. TVs and related peripherals contribute of the order of 700 MtCO₂e, nearly as much again as the total for global ICT.

Consumer equipment, where devices have small individual impacts, often have very substantial impacts overall due to the large volumes involved and shorter product life compared to infrastructure systems - so impacts from manufacturing and disposal become at least as significant as energy consumption.

7.2 Case studies

The 2G/3G case study considered the environmental impacts of mobile networks representative of current UK networks, and we conclude that the carbon footprint of cellular mobile networks is substantial within telecommunications, with the dominating contributors being network use-phase energy consumption and embodied carbon in handsets. Handsets have a relatively low use-phase impact in terms of energy consumption, but have a substantial impact when overall life cycle impacts are considered (manufacture, distribution, disposal/recycling) as a result of their short product life, typically 1-2 years for a significant proportion of handsets in the UK.

Whilst the energy consumption of 3G base stations can be at least as good as 2G base stations (for an equivalent number of voice circuits and operating at the same carrier frequency), the growth in 3G broadband mobile data services is a significant environmental issue. Subscriber-pull for the full range of 3G high data-rate services will create pressure to deploy more network resource.

The digital terrestrial TV (DTT) case study looked at the main impacts of both the transmission system and of consumer equipment, concluding that for the network, the operating (use phase) energy consumption is the dominant impact. The long service life of network equipment results in low annual contributions from embodied carbon (manufacturing and installation) and from recycling, as these are averaged over the expected life of the system (10-20 years upward).

The DTT network will ultimately provide an environmental advantage compared to analogue, but not while both networks are still operational. However, DTT transmission network power consumption is significantly overshadowed by the use-phase energy consumption of domestic TV sets and of other receiving equipment, this being of the order of 50 to 100 times greater than the total network consumption.

The consideration of a theoretical scenario of satellite broadcasting fully replacing DTT at some point in the future concludes that the environmental benefits would be relatively modest, given that consumer equipment is the dominant contributor compared to the DTT network, and that there would be additional impacts as part of replacing consumer equipment and installing new domestic
The femtocell case study considered the deployment of femtocells in the home to provide indoor 3G coverage. It concluded that femtocells could have a considerable operational energy advantage over the hypothetical alternative of expanding the macrocell network to provide approximately similar indoor coverage.

Based on our analysis, the large communication systems studied in detail in this report are making a relatively small but noticeable contribution to total UK CO\textsubscript{2}e emissions (Table 7.1).

<table>
<thead>
<tr>
<th>Communication system</th>
<th>Approximate energy consumption GWh/year</th>
<th>Approximate emissions MtCO\textsubscript{2}e/year</th>
<th>As % of total UK emissions</th>
<th>As % of total UK domestic emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>3G transmission networks</td>
<td>300</td>
<td>0.18</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>2G transmission networks</td>
<td>1000</td>
<td>0.60</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>DTT full transmission network (2012)</td>
<td>114</td>
<td>0.07</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Domestic TV equipment</td>
<td>5900</td>
<td>3.54</td>
<td>0.57</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Table 7.1. Case study examples contrasted with UK 2010 greenhouse gas emissions

This emphasises that the impact of TVs and related equipment are particularly significant, being widely deployed consumer products with daily usage. Active mode TV power consumption is proportional to screen size, and the introduction of increasing screen sizes (in part driven by HDTV developments) is a significant negative step in terms of environmental impact, encouraging higher energy use, the replacement of existing sets that may not have reached the end of their operational life, and the associated replacement of DVD players.

The EU and Defra initiatives to target consumer equipment energy and standby consumption are thus well justified, but the active (on mode) power consumption of the TV set remains a priority, as it contributes the most to total daily set consumption – typically around 80%\textsuperscript{80}.

With regard to next generation networks, a range of activities were identified in the study which are working to address environmental issues for fixed broadband and FTTx networks, including work by the FTTH Council and the ITU. Similar to other systems, it is evident that direct (1\textsuperscript{st} order) FTTx impacts are use-phase energy consumption of the fixed network and of consumer equipment; manufacturing and deployment impacts of new infrastructure and consumer products; and most significantly, the impacts of civil installation works required to deploy fibre at regional and national levels.

7.2.1 Network transition

The evolution of physical systems over time, and particularly the transitions between older and newer generations of communication systems, has a very important influence on environmental impacts. New systems are often implemented to provide new or enhanced services and geographic coverage, whilst supporting broadly similar core services to existing ones.

This transition can last a shorter period, if an explicit migration strategy is adopted, or for very many years (decades) if market demand, commercial viability or other factors sustain the demand for both older and new systems and services.

\textsuperscript{80} New generation OLED technologies offer the prospect of significant improvements in the longer term, albeit at the environmental cost of further product replacement impacts.
We conclude that, from an environmental perspective, major migrations to newer systems need to be planned so as to minimise the extent to which multiple physical systems and products co-exist, whilst meeting commercial, regulatory and public benefit requirements. However, decisions affecting the introduction of new generations of communication systems typically involve several parties across industry and Government, so Ofcom may only have certain opportunities to influence transition strategies.

In this context Ofcom might wish to investigate the development of better tools to analyse and identify optimum transition strategies for given cases, which would take account not just of technical and environmental system aspects, but also requirements such as continuity of service requirements, return on investment issues, equivalence of coverage, and the need to maximise consumer product lifetimes.

7.2.2 Network duplication

With regard to current mobile networks, it may be argued that multiple network operators and network duplication have been essential factors in achieving a thriving competitive communications services market in the UK, but now carries an environmental penalty. This is an example of where what is good for the consumer (e.g. choice and competitive pricing) can be bad for the citizen (e.g. negative environmental consequences). In this context, network sharing, which 3G network operators are beginning to embrace, should be further encouraged by Ofcom.

Recommendation: Consider mechanisms to promote reductions in the duplication of physical communications infrastructure, particularly in respect of cellular mobile networks. In this context, current industry activity to find ways to improve sharing of existing base station sites and equipment is encouraging, and the announcement by French regulator ARCEP calling for a sharing framework to be developed by French mobile operators, is a specific example of regulatory intervention to gain environmental (and other) benefits.

The work of the femtocell and 2G/3G case studies confirmed the importance of the lower frequency bands from an environmental perspective, especially in the context of rural and indoor coverage, as fewer base stations are typically required. The ‘800 MHz band’ liberated by analogue to digital TV switchover thus represents an opportunity to enhance mobile services both from an economic and from an environmental impact perspective, compared to using higher frequency bands.

Recommendation: With the environment in mind, we encourage Ofcom to consider spectrum packaging and sharing regimes to maximise the utilisation of the DDR spectrum made available for mobile services.

Recommendation: We suggest that Ofcom tracks the results of the Mobile Virtual Centre of Excellence (MVCE) Green Radio project. This 3½-year project that started in 2008 is understood to be looking at optimum architectures for wireless systems from an environmental point of view. The work is likely to yield results that complement the findings of this study.

7.2.3 ‘What might have been done differently’

Addressing the question of ‘what might have been done differently’, we conclude that when DTT was originally planned (or if it were being considered today), a decision for a faster switchover from analogue could have reduced the impacts of parallel network operation, and allowed a more optimised ‘green’ replacement strategy of consumer equipment. Introduction of power consumption limits and reduction targets directly into UK receiver specifications would also have been beneficial.

More radically, a detailed evaluation of digital television via satellite might have been conducted at
the outset, compared to implementing a new terrestrial network. Ofcom might have considered this from both a coverage perspective and from the potentially greater transitional issues, particularly regarding the need for a satellite dish on all dwellings, and dealing with satellite blind spots in urban areas. The DTT case study concludes that this approach could have reduced landscape impacts and network energy consumption, but with the possible downside of higher active energy consumption (and cost) for consumer receivers, at least in the earlier years.

For 2G and 3G mobile cellular, a formal transition strategy was never defined and there was no assumption that 3G would necessarily replace 2G, given there were complex issues which included national UK coverage requirements, the challenges of 3G system and handset technology development, and returns on investments for 2G operators.

As an example of alternative decisions that might have been considered, earlier introduction of requirements to restrict handset subsidies by operators could have created a more independent handset market, and encouraged users to keep their mobile phones for longer before upgrading.

On the network side, a single 3G physical network, licensed to an infrastructure service provider offering shared network access to competing 3G operators, could have offered a more optimised network in terms of environmental impacts, whilst meeting total coverage and capacity requirements. Alternatively, passive or active network sharing (including national roaming) might have been mandated.

With regard to the 3G spectrum auctions that took place in year 2000, it is possible to envisage how incentives might also have been explored to encourage improvement over time of the environmental footprint of systems. An example is the use of staged/tiered payment structures (with financial bonuses or penalties), implemented against performance improvements over time via agreed environmental criteria.

7.3 Positive impacts

The potential for communication systems to provide positive environmental benefits is significant; however these benefits are not an inevitable consequence of greater uptake of systems and services. Rather, communications systems and services are critical enabling elements, essential to implement wider initiatives and policy changes that in practice are the actual drivers of actions and changes in behaviours. It is these that (may) then lead to reductions in environmental impacts in other areas.

Whilst direct 1st order direct impacts are the quantifiable effects of deploying and using communications systems, positive (and negative) 2nd and 3rd order impacts are the possible effects arising from the services provided and the changes these cause.

Quantifying and attributing positive impacts to communications is more complex than for direct negative impacts, relying on many more assumptions as to the likely take up and the effectiveness of applications and services. Our conclusion from reviewing a number of the current studies of communications and ICT impacts, is that many take an optimistic view of the positive benefits that ICT can provide, without taking due account of other necessary regulatory, policy and behavioural change issues necessary to achieve the expected benefits. Further, the baselines, scope and methods for including these positive effects as used by these studies may be different to those that Ofcom might wish to consider (based on its public interest remit), so care is needed when interpreting such data.

A detailed examination by Cairns/TRL on how teleconferencing can reduce business travel (if it is introduced to do so in a travel minimisation context) reveals complementarity as well as substitution, i.e. teleconferencing improves business efficiency when used as an adjunct to existing practices and physical meetings. This often depends on the purpose and style of individual businesses, and overall greater use of telecommunications may not automatically reduce travel. Similar arguments apply for remote/home working, where rebound effects such as additional
journeys and home energy use may offset benefits in reduced travel to work.

Nonetheless there are clear arguments that communications services can be effective in offsetting travel and emissions in other sectors, but they must be supported by other necessary actions, such as setting appropriate policy and implementation objectives and developing users’ skills. Ofcom has a key role in encouraging the timely introduction of communications infrastructure (such as next generation networks/FTTx and mobile broadband) and the adoption of relevant technologies, which can then be exploited by the market.

We also conclude that communication systems also have potential to help reduce energy use in other sectors via intelligent monitoring and control, with resulting reductions in emissions (and energy costs).

Recommendation: Ofcom could explore favourable spectrum licensing arrangements for specific communication services and applications that have potentially positive environmental benefits - for example smart metering and travel information/automation systems. These arrangements might include discounted or deferred payment mechanisms for successful implementation of services. Where application specific licence-exempt spectrum is appropriate (e.g. for monitoring and control of building energy use), a small amount of dedicated spectrum might be allocated on a national basis to actively encourage the development of ‘environmentally-related’ applications.

### 7.4 Communication services - growth versus impacts

Considering the nature of communication systems and services as a whole, we conclude that a fundamental balance must be continually struck between, on the one hand, the increasing environmental impacts as systems and services grow, as technology and markets develop and as more hardware and products are deployed, and on the other hand, the benefits delivered by such systems and services (Figure 7.1). Benefits include social and economic benefits as well as commercial ones, as communication systems are an increasingly essential element for the functioning and growth of the UK economy, providing desirable services to citizens, consumers, business and Government. This tension is considered to be a key challenge for the communications industry going forward.

The introduction of digital TV provides a good example in terms of spectrum usage. DTT brings benefits compared to the previous analogue transmission system, as a result of advances in technology such as efficient modulation and advanced compression techniques. The result is more channels transmitted in significantly less spectrum, with less network energy consumption compared to analogue. Paradoxically, however, this makes it possible to operate more systems in the same amount of spectrum and thereby possibly increases environmental impacts in the future.
Practically, it is useful to consider that all communication systems have some associated environmental ‘costs’, which must be accepted in order to obtain the benefits the systems provide. Environmental consideration then dictates that wherever possible these costs (impacts) be minimised and reduced over the full life of each system. This is especially important when multiple, duplicated, systems provide similar services. If needed, mechanisms (licensing, regulation, standardisation) can then help promote environmentally responsible implementation and action by industry.

**Recommendation:** Licensing incentives that encourage good environmental practice could be considered, to encourage improvement over time of the environmental footprint of systems. For example, payment for spectrum access granted through an auction might be phased such that discounts are awarded or penalties levied depending on how well agreed environmental goals are achieved (potentially linked to system deployment and operational time periods).

In this context, assessing absolute impacts is more useful than trying to compare relative environmental impacts of systems and products. If the absolute impacts of a system are determined to be substantial, actions to minimise and continually reduce them are worthwhile - even if the impacts can only be determined to a given accuracy. If absolute impacts are small, then there is a
lesser environmental priority to address them. Minimising the absolute impacts of all systems is the key issue for Climate Change.

Whilst many observers make the case that communication systems help enable significant reductions by their positive 2nd/3rd order effects, the level of direct impacts of major systems is such that these should nonetheless be actively addressed - the positive offsetting potential of communications should be seen as additional benefit, not as a reason to ignore their direct impacts.

7.5 Ofcom involvement

The introduction of new communication systems and major developments in existing ones can require the involvement of various groups from both Government and industry. Factors affecting environmental impacts may be influenced by a range of bodies, depending on whether they relate to technical aspects of the system, commercial considerations, or Governmental/national decisions regarding service levels, competition and coverage.

A simple illustration for the case of DTT is shown in Figure 7.2. (NB: original DTT planning involved previous bodies such as the DTI, ITC and others). UK DTT is based on original DVB (now ETSI) standards, but with specific UK technical details decided by the UK DTG group. The Government defined implementation and analogue switch-off decisions, with Ofcom responsible for spectrum allocation and licensing. Original DTT impact evaluations were conducted by DCMS as input to Government decisions, whilst energy consumption of products is (now) addressed by Defra and by operators and manufacturers implementing Defra and EU directives and guidelines.

This collaborative approach is true for many other systems, so that only specific areas fall within Ofcom’s remit to potentially consider environmental issues - primarily spectrum planning and licensing and system requirements to adopt ‘greener’ technical standards.

Currently, much cross-sector activity is underway to address environmental issues, including the EU Energy using Products (EuP) programme and directives, Defra’s Market Transformation Programme (MTP), and the activities by the ITU and ETSI. At the same time, manufacturers and operators are increasingly working toward reducing the environmental impacts of their own businesses and products, as part of reducing operational and energy costs (a ‘win-win’ situation in many instances), reducing their materials use and recycling costs, and as part of commercial competition to promote ‘greener’ positioning in the market.

Good progress is already happening, and we conclude that regulatory intervention by Ofcom (as compared to coordination) is in many cases likely to be unnecessary or counterproductive. However there appears a lack of clear direction or guidance specific to the communications
industry, a sentiment also expressed by a number of industry representatives interviewed.

Recommendation: Ofcom could consider (as communications regulator) coordinating and/or leading work on common baselines appropriate to the communications industry for environmental analysis, and identifying environmental priorities and the emphasis that these should be given in future.

In this regard, Defra and BERR staff suggested during the study that Ofcom involvement in environmental issues could be valuable, in order to coordinate work on different policy issues. In addition Defra suggested that, in relation to environmental issues, Ofcom should be neither too active (i.e. no need to generate new initiatives, there are already plenty going on), nor too passive (i.e. not oblivious to them).

Recommendation: Ofcom could consider developing dialogues with Defra, BERR and DECC to ensure awareness of activities and to consider possible coordinated initiatives, within the overarching policy initiative of the Sustainable Development Strategy in Government.

In summary, Figure 7.3 illustrates the scope of potential activities that Ofcom might wish to undertake from an environmental perspective.

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**Figure 7.3 Possible Ofcom activities going forward**