A.6 Application 6: Wireless home entertainment networks

A.6.1 Description of the application

What is the application?

In its market analysis Ovum defines a home network as the network which enables two or more intelligent devices in the home to connect to each other and to the outside world. We use this definition in this profile.

Ultimately, home networks will enable entertainment, information, communications and security devices, in addition to appliances in the home, to communicate with each other. These devices and appliances will share information and be controlled and monitored both within the home and remotely by users. All home networks will require a service element to ensure the day-to-day running of the system.

In assessing how demand for home networks will evolve we need to consider the three main uses of home networks – data networking, home entertainment and home automation separately.

Home data

Driven by a range of factors, such as rising broadband penetration, more widespread multiple PC ownership and the increasing availability of wireless networking equipment, home data networks are now mainstream products.

Shared access from multiple PCs to broadband services is the major driver for acquiring a home network. Wireless technologies have a major share of this market because they need no additional wiring installation. However, Ethernet over structured cabling remains the choice for the enthusiast because of its higher bandwidth and QoS capabilities.

Other network technologies are less significant by virtue of declining vendor support, geographic limitation or simply lack of awareness. HomePlug (a PLC technology) is a good solution but to succeed it needs much more active marketing, and products that match the price point of wireless.

Home entertainment

In contrast to home data networking, home entertainment networking is in its infancy. It refers to the conveyance of content to various devices in the home either via a home media server or through an independent content supplier. The content can then be transferred between devices located in the home and from home based devices to portable devices for added convenience and flexibility.

The network appliance market is starting to develop with Internet radios, jukeboxes and players appearing. These are a natural add on for users that are building digital music collections. Equally, the digital photograph market has spurred interest in appliances that can present stored photos on a TV.

New applications include the creation of picture libraries and music distribution (using home jukebox). These differ from current applications because they are less PC-centric. Users might also want to listen to music on the home stereo system (via an appliance such as the Squeezebox) and view photos on a television. The place where the data is stored is no longer where it is used and home networks with new capabilities are needed to support this market.

Many of the current music appliances use proprietary digital rights management (DRM) technology. Once users have a number of networked appliances they will find their options limited by this proprietary software e.g. to devices employing the same DRM system.

While home entertainment networking has substantial potential, the way in which the market will evolve is still far from clear. A number of issues remain largely unresolved. For example:

- Where will digital content be stored? In particular will devices access a single server located in the home, will they us a server in a wide area network or will all content be stored on all devices?
- What bandwidth is required for a home entertainment network? Given the likely explosion in demand for HDTV and the move to individual viewing of TV content, will the current bandwidth at 2.4 and 5 GHz be sufficient or will greater bandwidth be required in the long run?
- Which kinds of players and which standards will dominate in home entertainment networking. Lack of common standards and interoperability will hold back the development of this market in the short term as a wide range of players tries to satisfy their own interests. For example:
  - In the consumer electronics industry manufacturers of entertainment equipment could be tempted to go into a 'standards war', in which individual manufacturers seek to establish their own proprietary standards as the de-facto standard.[95] Unless major players can co-operate and agree on architectures and protocols, we may see a repeat of the Betamax versus VHS format wars, with inevitable winners and losers, amongst both industry players and early adopters
  - In the software industry various players are also trying to establish their software/operating systems as the de-facto standard to enable the various devices to 'talk' to each other. We expect a battle between Linux and Microsoft as they strive to dominate the market
  - The media industry will have to re-format its outputs in a range of digital formats for the new devices. It will also be concerned about cannibalising revenues from traditional products such as CDs, videos and DVDs, as well as the threat of piracy. The industry will ensure that digital rights management (DRM) is built into the propositions from other industry players.

Home automation
Currently this is mainly a hobbyist market, but interest is growing

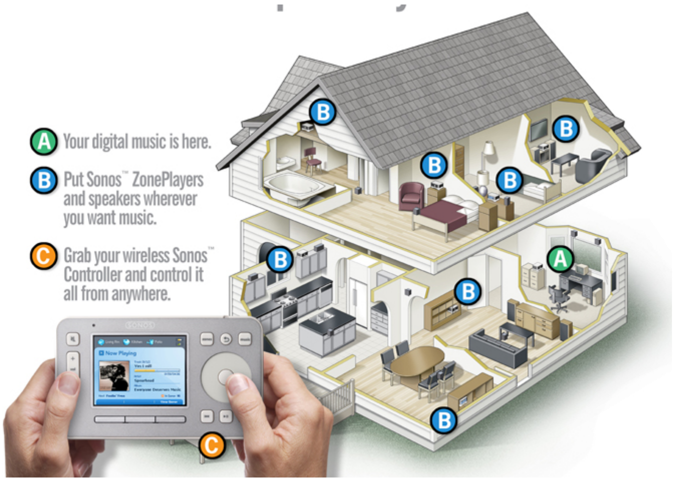
- Home automation remains focused on the US market and hobbyists. 'Professional' solutions are very expensive but use superior protocols, making them more reliable and more responsive.
- X10 is the primary protocol used in consumer control devices. Since the expiry of patents related to the technology, a growing number of control devices and suppliers have come to market. Users can now buy modules for many lighting control, control of heating, ventilation and air conditioning (HVAC) and home security applications.
- Computer interfaces are available (with both proprietary and open source software support) that enable a PC to control X10 devices. In turn this enables applications that provide remote monitoring and control over the Internet. XAP is a collection of UK-based developers aiming to standardise home control through X10 and other protocols. It is also developing applications.
- Although home automation technology has grown in capability and declined in cost, it faces a challenge of user awareness. It is not widely publicised outside the US and many users probably feel they can do without the typical applications. It is most likely to grow by pull through from data networks where user curiosity is stimulated through other networked applications.

[95] For example for high definition DVDs

Integration of home network services

There are clearly cost savings in integrating home data, entertainment and automation networks. But, given the current uncertainty over market developments in home entertainment networking, it is not possible to predict with any degree of certainty when or how such integration will occur. Nonetheless, there are products available now that combine home data and some forms of home entertainment. For example the Sonos[96] wireless streaming media system that allows users to connect and then stream music from the media centre around the house via the system's built-in mesh network, as illustrated in Figure A.37.

Figure A.37 – Sonos multi-zone digital music system



Who are the users?

Home networks are aimed solely at the consumer market and there are currently three main types of home networks for different purposes:

- Home data. Similar to office networks, this is the most established type of network, which enables users to transfer data and share a broadband connection through interconnected network appliances such as PCs, laptops and PDAs
- Home entertainment. These networks connect various audio/video devices within the home
- Home automation. These networks mostly control and monitor domestic heating, ventilation and air conditioning (HVAC) systems, as well as lighting and security or individual household appliances, using the Web, email or the telephone as an interface.

In the long term, we expect progressive convergence of these application areas towards a unified home network.

A.6.2 Technical characteristics

Networked or smart homes rely on the ability to distribute information and commands around the home. There are a variety of ways that this can be achieved. Broadly these can be divided into wired and wireless methods.

[96] http://www.sonos.com/products/?tref=ghome

Wireless communication involves a more emergent set of technologies. These are widely used for home data networks but have only limited use to date for home entertainment networks because it has been difficult to provide the required sustained data throughout to support real-time entertainment applications such as TV distribution. Coverage and quality of service have been hard to achieve although solutions are now emerging. In the short-term, home data and entertainment networks will operate as two separate entities, however, from 2016 we expect to see an interoperable single hub controlling the data and entertainment networks within the home.

Wired home networks

Dedicated wiring bus

A wiring bus is a dedicated wiring system installed purely for the purposes of distributing information. Typically a communications bus will rely on an unshielded twisted pair cable (UTP), which is a cable with at least two separate wires insulated from each other but without any sheathing to prevent interference from radio waves. The most common form in an existing home is the telephone cabling. In the smart or networked home a better quality cable than this is required, usually Category 5 (Cat 5) network cabling, which is also used for computer networks in modern offices. Cat 5 cabling consists of four pairs of cables, potentially allowing four sets of signals to be sent over the same cable.

Power line communication (PLC)

Power line communications involves the use of the existing power network to carry data signals in addition to the 240V supply. PLC can be a very effective medium for installations in existing homes as it can require very little rewiring. But PLC is limited to a relatively narrow bandwidth as a result of UK legal regulation on the usable frequencies. This limited bandwidth makes it more useful for relatively simple message, such an on, off or dim, rather than more complex signals, such as video transmission.

Wireless home networks

Infrared communication

The use of infrared transmitters and receivers in the home is already fairly common. Remote control units for audio-visual equipment almost exclusively use infrared spectrum to communicate with their appliances. Infrared can also be used for more general communication purposes in the smart home. Very few systems have been developed in practice, however, as a clear line of sight between transmitter and receiver is required.

Radio frequency communication

An emergent medium for smart homes is the use of radio signals to communicate. New standards developed initially for computers are now starting to be applied to smart homes. WiFi, the IEEE 802.11b standard for wireless computer networking, and Bluetooth, a standard for short range wireless communication for computers, peripherals and mobile telephone, have both been suggested as new mediums for smart homes communications. WiFi operates in the LE 2.4GHz spectrum band and provides up to 11Mbps transmission which is comparable to Ethernet.

Use of spectrum

In the short-term, wireless spectrum at the 2.4GHz and 5GHz ranges provided using WiFi is sufficient to run simple home entertainment networks. However, there is an issue with interference from Bluetooth, microwave and other WiFi networks which are also used in the home. This may eventually force users to migrate to alternative wired technologies or other LE bands to improve the quality of their home network. One promising option is to use a wired backbone with wireless access - perhaps using spectrum in the over 30 GHz range[97] - within each room.

A.6.3 Evolution of demand

Future prospects of wireless home networking

Drivers for and barriers to growth

There is now more clarity on the drivers of demand for home networks as new applications develop:

- Increasing broadband access continues to be one of the biggest drivers of home networking since broadband users typically also have more than one device capable of networking in their home. The trend is towards greater penetration of broadband services; this can only boost the home network market.
- There is an increasing variety of networked devices in the home. The number of multiple PC homes continues to rise on a global basis. Users are experimenting with PDAs and network appliances, adding new terminal types within the home network.
- New application drivers include picture libraries and music distribution (home jukebox)
- Network product availability is also increasing – many high-street stores now sell a limited range of (usually wireless) network equipment.

There are also a number of barriers to home networking:

- As various players aim to stake their claim on this new market, it is being held back by the lack of compatibility amongst devices, their limited availability and their high cost. Various groups, such as the Digital Living Network Alliance (formerly known as the Digital Home Working Group) have been trying to deal with some of these issues, with limited success to date.
- There is still some way to go to make home networks easy for non-technical users to set up. 'Plug and play' is still more like 'plug, fail, read, tinker, play' with the user often needing to enter some technical information to achieve success. Wireless has made things simpler but brought some problems of its own. The burgeoning variety of wireless technology is confusing for end users
- Lack of convergence on Ethernet from consumer electronic vendors is hindering the market. Most consumer electronic vendors use proprietary technology or FireWire. The range of these networks is limited to just a few metres, making them unsuitable for networking an entire home.
- Many consumers are unaware of the possibilities of home networking, and even those who are will generally not be convinced of the benefits of a home entertainment network until various devices can be added to it effortlessly and spontaneously
- Consumers are also wary of buying products that are not future-proof in this fast moving market, where devices can become obsolete within months of being launched as superior technologies emerge. In the meantime, they will continue to buy home entertainment equipment such as hi-fis and TVs as standalone devices.

Substitutes

Clearly wireless and wired technologies compete to provide home networks. It is difficult to predict what proportion will use wireless. In the Ovum projections of Table A.48 – Demand scenarios this

[97] This would connect high throughput devices over a few metres providing there were no intervening walls.

proportion rises from 66% in 2006 to 72% by 2009. But this trend might reverse as the higher throughput requirements of home entertainment networks, combined with strong demand for them, creates a need for wired or hybrid solutions.[98]

Household growth

There are 24.2 million households in Great Britain in 2005[99] and 660,900 in Northern Ireland in 2005[100]. This will grow to 25.7 million in England[101], 2.5 million in Scotland[102], 1.471 million in Wales[103] and 815,500 in Northern Ireland[4] by 2025[104]. This equates to a household growth rate of approximately 1.1% per annum for the UK as a whole.

Home networks

Table A.47 provides Ovum's home network forecasts for the UK. These forecasts cover data and automation but not home entertainment networks[105]. From the forecasts, we can see that wireless accounts for 66% of home data network connections in 2006, rising to 72% in 2009.

Table A.47 – Home network forecast in the UK

	2004	2005	2006	2007	2008	2009
Data networking technology (000s)						
Ethernet	309	553	759	905	995	1,034
Other wired	48	118	214	331	460	558
IEEE 802.11	499	1,136	1,924	2,763	3,574	4,264
Total	856	1,807	2,897	3,999	5,029	5,856
Number of home network nodes (000s)						
Ethernet	710	1,445	2,223	2,942	3,558	4,027
Other wired	111	307	627	1,076	1,644	2,291
IEEE 802.11	1,149	2,965	5,634	8,983	12,771	16,602
Total	1,970	4,717	8,484	13,001	17,973	22,920
Home automation (telecontrol & telemetry)						
Number of homes with home automation (000s)	80	150	231	327	438	561

Source: Ovum; the IEE 802.11 line shows projected demand for wireless home networks

[98] e.g. with a wired backbone and wireless connections in each room
[99] Table 2.1, ONS (2006) Social Trends 36
[100] Household projections, Northern Ireland Statistics and Research Agency, http://www.nisra.gov.uk
[101] http://www.communities.gov.uk/index.asp?id=1002882&PressNoticeID=2097
[102] http://www.gro-scotland.gov.uk/statistics/library/household-estimates-projections/index.html
[103] http://www.wales.gov.uk/keypubstatisticsforwales/content/publication/housing/2006/sdr30-2006/sdr30-2006.pdf
[104] http://www.communities.gov.uk/index.asp?id=1002882&PressNoticeID=2097
[105] Ovum estimates that currently less than 1 per cent of homes with a data network have entertainment networks

Demand scenarios

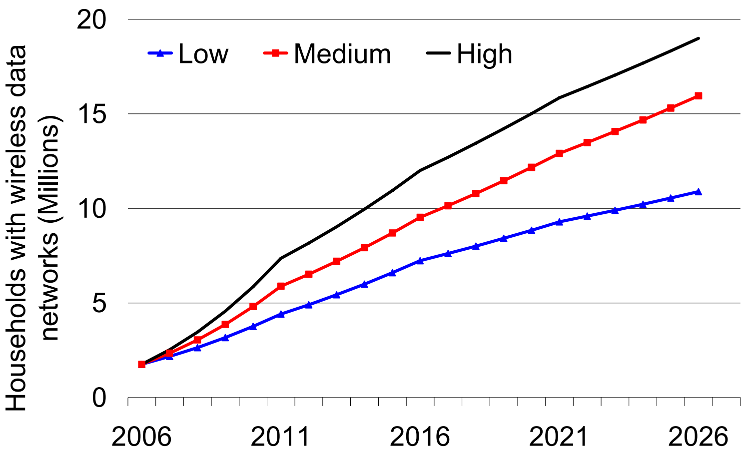
Given the current high levels of uncertainty about how the home entertainment network market might evolve we focus our efforts on making projections of demand and economic value for home data networking. Based on the analysis set out above we propose the three demand scenarios of Table A.48. The 2006 estimates and the 2011 projections for the medium demand scenario in this table are consistent with the Ovum projections of Table A.47.

Table A.48 – Demand scenarios

	2006	2011	2016	2021	2026
UK Broadband penetration	46%	75%	85%	90%	92%
Proportion of broadband users with home data networks					
Low demand scenario	23%	30%	38%	41%	43%
Medium demand scenario	23%	40%	50%	57%	63%
High demand scenario	23%	50%	63%	70%	75%
% of wireless home data networks	66%	74%	80%	85%	90%

Figure A.38 then presents our demand projections for home data networking under these three scenarios.

Figure A.38 – Households with wireless home data networking – 2006 to 2026



A.6.4 Economic value

There are potentially a number of sources of economic value in the use of home networks:

- Different devices can share a single broadband connection. This is the prime benefit of home networks and applies to data, entertainment and automation networks equally
- Greater convenience stimulates demand for complimentary products. For example photo printers, speakers etc to make the most of the entertainment system. This benefit applies mainly to home entertainment networks

- More free time to spend on entertainment/leisure etc if everything can be networked and available throughout the house. Networked entertainment system reduces need to go to cinema/music or video store for entertainment. Again this benefit applies mainly to home entertainment networks
- Increased energy efficiency. The ability to programme devices to turn on/off only when required reduces energy consumption. This benefit applies to home automation
- Improved security, and reduced cost of crime. Use of automation products within the networked home to improve security (e.g. lights on when away from home etc) should reduce crime levels. Again this benefit applies to home automation.

We focus on the quantifying the benefits of home data networking using wireless rather than wired technologies. We use as our counterfactual a scenario in which wireless home data networks are not used. In so doing we quantify the costs and benefits tabulated in Table A.49.

Table A.49 – List of quantified costs and benefits

Benefits	Quantified?	Costs	Quantified?
Home data network			
Additional consumer surplus generated from stimulation of residential broadband	Yes	Cost of wireless router	Yes
Avoided cost of wiring the home plus more flexible use of networked devices in the home	Yes	Cost of wireless router less cost of wired hub	
Home entertainment network			
Part of enhanced willingness to pay for home entertainment products which can communicate	No	Cost of hub	No
Avoided cost of wiring the home	No		
Flexible use of networked devices in the home	No		
Home automation network	No		
Cost saving from integration of home data, entertainment and automation networks	No		

There are two categories of home wireless data network user:

- Category 1: those who adopt a wireless network as an integral part of a decision to become a broadband household. The net incremental benefit for this category of users is the full consumer surplus from use of broadband less the cost of the wireless router
- Category 2: those who use a wireless network in preference to a wired network – either as part of the decision to adopt broadband or subsequently when moving from simple broadband to networked broadband. Here the incremental benefit is the avoided cost of wiring the home (net of any additional equipment costs) plus the more flexible use of networked devices in the home

To estimate these benefits we use the following model. Let:

WHD_t = Number of wireless home data networks in year t

x_t = % of households which adopt broadband because of the existence of wireless networks

CS_t = consumer surplus per household from residential broadband

b = benefit per household from increased flexibility and avoided wiring costs which comes from a wireless network

c_1 = cost of wireless router

c_2 = cost of wired hub

Then the net benefits for Category 1 users of wireless networks is given by

$x_t \cdot [CS_t - c_1] \cdot WHD_t$ in year 1

$x_t \cdot CS_t \cdot WHD_t$ in all subsequent years

and the one-off net benefits for Category 2 users are given by:

$[1 - x_t] \cdot [b - (c_1 - c_2)] \cdot WHD_t$ only in the year of installation

In each case we consider only the initial purchase cost of the wireless router and not any subsequent replacement purchases.

We set out in Table A.50 the assumptions we make about each of these variables for each of our three scenarios. Figure A.39 then presents our projections of the net benefits of home data networking using wireless and Table A.51 the NPVs of these benefits streams.

Table A.50 – Assumptions used in projecting the net benefits of home data networking

Variable	Value	Source/comment
Number of wireless home data networks	See Figure A.38	
% of households which adopt broadband because of the existence of wireless networks	20%	Ovum and Indepen assumption
Consumer surplus per household from residential broadband (£ per month)	10	See text
Benefit per household from increased flexibility and avoided wiring costs which comes from a wireless network (£)	200	Same as for Application 10 (home alarm systems)
Cost of wireless router (£)	£100 in 2006 reducing to £40 in 2026	Reflects price trends for mass electronics products with increasing functionality
Cost of wired hub	50% of cost of wireless router	

As Table A.50 shows we assume that the average consumer surplus from use of home broadband is constant at £10 per month. Indepen used this assumption in a recent study on the benefits of broadband.[106] It reflects assumptions that:

[106] The broadband case study in BRT study "Restoring European economic and social progress" published by Indepen in January 2006

- A consumer's willingness to pay is constant. The increasing value of broadband (which increases willingness to pay) is offset by marginal customers (with lower willingness to pay) becoming broadband users
- The price of residential broadband is constant. Falling prices are balanced by a rising requirement from consumers for higher bandwidth.

Figure A.39 – Annual net economic benefits of home data networking (£m)

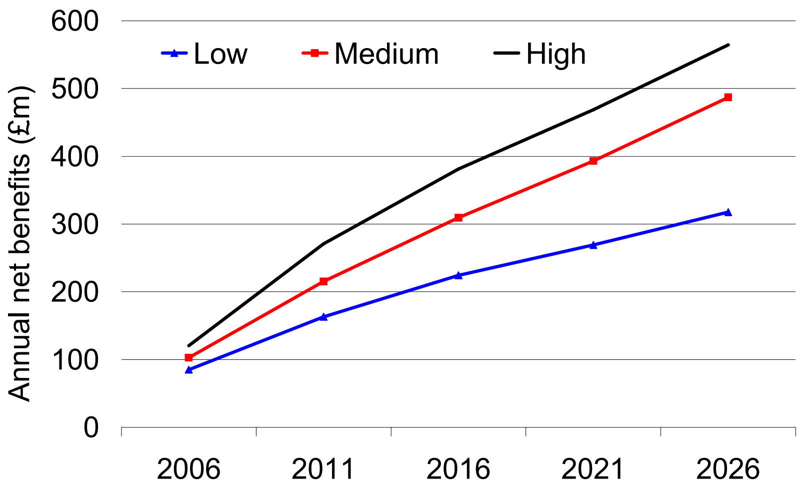


Table A.51 – Total net present value of wireless home data networks

Scenario	Net present value (£m)
Low demand scenario	4317
Medium demand scenario	6205
High demand scenario	7464

Detailed forecasts for each of the scenarios are given below.

Table A.52 – Annual benefits of wireless home data networks – Low demand scenario

Low scenario	2006	2011	2016	2021	2026
Households in the UK (Millions)	25.1	26.5	28.0	29.6	31.3
Total broadband households (Millions)	11.5	19.9	23.8	26.6	28.8
Households that use broadband because of existence of wireless home networks (000)	351	883	1,448	1,857	2,178
Annual installations of wireless home networks in such households (000s)	83	98	75	61	69
Costs of wireless routers (£)	-100	-85	-70	-55	-40
Additional installation costs of wireless home networks in these households (£m)	-8	-8	-5	-3	-3
Consumer surplus from having broadband (£ per year)	124	124	124	124	124
Total consumer surplus from having broadband (£m)	44	110	180	231	270
Net benefits from having wireless home networks (£m)	35	101	174	227	268
Households that replace wired networks with wireless (000s)	1,402	3,532	5,792	7,428	8,711
Annual installations of wireless networks (000s)	332	392	302	243	278
Additional costs of wireless routers (£)	-50	-43	-35	-28	-20
Avoided cost of wiring a home (£)	200	200	200	200	200
Cost savings from installing wireless home networks (£m)	50	62	50	42	50
Total benefits (£m)	85	163	224	269	318

Table A.53 – Annual benefits of wireless home data networks – Medium demand scenario

Medium scenario	2006	2011	2016	2021	2026
Households in the UK (Millions)	25.1	26.5	28.0	29.6	31.3
Total broadband households (Millions)	11.5	19.9	23.8	26.6	28.8
Households that use broadband because of existence of wireless home networks (000)	351	1,177	1,905	2,582	3,191
Annual installations of wireless home networks in such households (000s)	119	127	123	114	134
Costs of wireless routers (£)	-100	-85	-70	-55	-40
Additional installation costs of wireless home networks in these households (£m)	-12	-11	-9	-6	-5
Consumer surplus from having broadband (£ per year)	124	124	124	124	124
Total consumer surplus from having broadband (£m)	44	146	237	320	396
Net benefits from having wireless home networks (£m)	32	135	228	314	391
Households that replace wired networks with wireless (000s)	1,402	4,710	7,621	10,327	12,762
Annual installations of wireless networks (000s)	475	507	493	457	534
Additional costs of wireless routers (£)	-50	-43	-35	-28	-20
Avoided cost of wiring a home (£)	200	200	200	200	200
Cost savings from installing wireless home networks (£m)	71	80	81	79	96
Total benefits (£m)	103	215	309	393	487

Table A.54 – Annual benefits of wireless home data networks – High demand scenario

High scenario	2006	2011	2016	2021	2026
Households in the UK (Millions)	25.1	26.5	28.0	29.6	31.3
Total broadband households (Millions)	11.5	19.9	23.8	26.6	28.8
Households that use broadband because of existence of wireless home networks (000)	351	1,472	2,401	3,170	3,798
Annual installations of wireless home networks in such households (000s)	154	161	141	118	137
Costs of wireless routers (£)	-100	-85	-70	-55	-40
Additional installation costs of wireless home networks in these households (£m)	-15	-14	-10	-7	-5
Consumer surplus from having broadband (£ per year)	124	124	124	124	124
Total consumer surplus from having broadband (£m)	44	183	298	394	472
Net benefits from having wireless home networks (£m)	28	169	288	387	466
Households that replace wired networks with wireless (000s)	1,402	5,887	9,603	12,682	15,193
Annual installations of wireless networks (000s)	617	646	564	473	547
Additional costs of wireless routers (£)	-50	-43	-35	-28	-20
Avoided cost of wiring a home (£)	200	200	200	200	200
Cost savings from installing wireless home networks (£m)	93	102	93	82	98
Total benefits (£m)	121	271	381	469	565

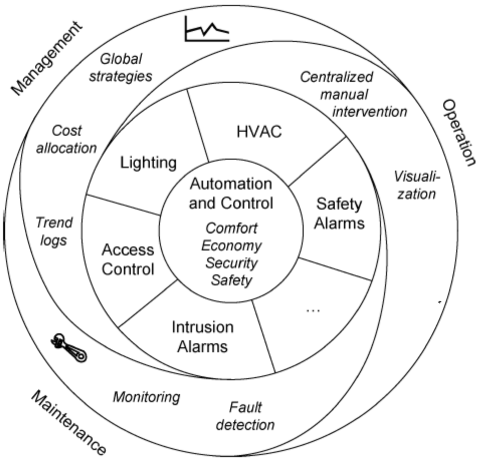
A.7 Application 7: Wireless building automation

A.7.1 Description of the application

What is the application?

Building automation systems (BAS) is concerned with the provision of automatic control of the conditions of indoor environments, in particular the automation of heating, ventilation and air conditioning systems (HVAC). Today, the scope of BAS has increased to integrate control systems for safety and access, as well as building operation, maintenance and management systems. All of these are encompassed in what is also known as "intelligent buildings" that optimise building management, leading to savings in energy consumption, lower installation, operation and maintenance costs, increasing the security level and raised comfort for the people inside the building. Furthermore, once an integrated system is in place, it is much more adaptable to changing user requirements.

Figure A.40 – Functional aspects of fully integrated building automation system[107]



An important driver to this integration is the development of wireless technologies, thus enabling new applications to be deployed and releasing the immense potential of integrated systems. Wireless building automation (WBA) involves the introduction of the use of wireless networking technologies in the management of public buildings or professional infrastructures. There is a whole range of technical equipment that could be included within this network:

- Computer networks
- Wireless access points
- Heating, ventilation and air conditioning (HVAC)
- Personal digital assistants (PDAs) for technical and security crew
- Surveillance and monitoring equipment and other wireless sensors

[107] Source: Kastner et al (2005) Communication systems for building automation and control, Proceedings of the IEEE, Vol. 93, No. 6

- Wireless controls that employ electronic or direct digital control (DDC) technology for control, monitoring and energy management functions using a variety of devices and equipment. These include room pressure and temperature sensors, actuators, constant and variable air volume systems, and unit ventilators
- Central control room from which the entire system can be operated

The building automation system in a typical office building can be complex and expected to perform without interruption. The system can have myriad control points and force legacy equipment to work alongside modern control hardware. Wireless technology has matured, with improved security and better transmission rates. Combined with building automation systems, wireless technology offers the potential for easy relocation, operational savings while offering reliable performance. Nonetheless, wirelessly integrated systems will still require the use hard-wired connections to provide a higher bandwidth backbone, for example, for streaming CCTV images.

In this profile we focus on those components of building automation which deal with HVAC and security, including energy management.

A.7.2 Technical characteristics

The biggest challenge with WBA is that the wireless network has to fulfil contradictory requirements. Sensors and actuators have to be as energy-efficient as possible because they are battery powered, whilst the network should be capable of supporting video surveillance and extend or even replace the wired backbone. In addition, the network should be able to support existing wireless devices such as PDAs and scalable to support the number of devices found in very large buildings. A networking technology that simultaneously fulfils these requirements does not currently exist. Instead, different technologies are combined in an appropriate network solution, including

- Wired backbone, providing IP backbone and achieving much higher throughput than wireless technologies
- Wireless LANs (WLANs), responsible for serving IEEE 802.11 b/g devices such as PDAs and laptops. These devices require a high bandwidth and a low latency (eg for video surveillance).
- Wireless mesh networks (WMNs).
  - Sensor networks have lower data rate payload and currently choose between the 915MHz and 2.4GHz frequency bands. They use one way communication between the sensors and a centralised sink which collects the sensor's data
  - Controller networks, will most likely need to operate in the 2.4GHz frequency band to support the higher data rates typical of them. As more products are used on a global basis we expect that the majority of wireless mesh networks (either sensor or controller types) will move to the 2.4GHz frequency band, which can be used in Europe, North America and most of Asia.

Wireless sensors are typically battery powered, but controllers are AC line powered and will most likely remain so for the foreseeable future, primarily because they are mounted adjacent to power-hungry actuators. Most of the research on wireless sensors has been focused on lowering their energy consumption.

Wireless controllers and actuators in a network present additional challenges, such as node heterogeneity, direct communication between sensors and actuators and real time communication. Furthermore, the increasing importance of quality of service (QoS), for example, for critical safety applications such as fire detection, and security issues creates a need for two way communication with the controller sending commands to the sensor as well as the sensor sending information to the controller.

Sensors and controllers also operate in different environments. Controllers are typically mounted out of the sight of building occupants. For many controllers this is in the open space of the ceiling plenum and characterised by a densely packed geometry of controllers within relatively close proximity to each other. Typical indoor ranges range for 50 to 150 feet and most controllers have numerous other controllers located within this range to guarantee multiple redundant paths of communication. Additionally, the vast amount of large, flat metal surfaces from duct work and other surfaces usually present scatter RF signals and improves propagation by allowing RF signals to bounce around corners until a node to receive the signal is found. However, this may at times also create issues with multipath interference, where a single wireless signal takes two different paths to its intended receiver and they are 180 degrees out of phase and cancel each other at the receiver.

Because mesh networks have redundant paths of communication this is not usually a problem. If one signal is cancelled there are likely other signals that are not affected. The overall effect is that controller nodes are easily able to establish communication with many other nodes and the typical controller environment is very conducive to a wireless mesh topology.

Room sensors, on the other hand, typically are located farther apart with more obstructions between them and in a more dynamic environment where obstructions are constantly in a state of flux and other RF devices are brought within close proximity. For example the movement of occupants, furniture, cabinets, and other obstructions along with the close proximity of other RF devices such as cell phones and wireless LANs create a challenging environment for room sensors.

However, even with all of these challenges, mesh technologies are being used successfully with sensors today, providing strong evidence that controllers with their AC line power and typically more "RF-friendly" environment would achieve the same level of success.

A.7.3 Existing examples of WBA

While wireless technology has been used already in small scale building automation (such as home networks) for several years, it has usually been deemed too unreliable or too expensive for use in commercial building applications. As a result current use of WBA in the UK commercial sector is currently negligible. In addition, connectivity issues and battery-hungry wireless devices have not made wireless solutions all that attractive. However, developments in the last few years are now changing the situation. There are already examples of WBA use in the commercial sector, especially in Asia. For example:

- Web-based controls for individual office lighting, air handling and window blinds, enabling each tenant to control their individual office environment with the click of their mouse.
- After hours security and HVAC system controlled by IP phones.
- Elevator, chillers, water, electricity, lighting and security all tied into the building IP network to allow the most efficient monitoring and maintenance of all building systems.
- Toll pass system for parking and garages that allows for wireless scanning and automatic billing for parking fees, motion sensors in each space to give a precise number of empty spaces, and scanners that read the license plates numbers to allow VIPs to park on a private level and access a secure lift.

- The laser light show in Hong Kong where around 20 buildings are networked together to create a visual display of aerial and coloured lighting on the building facades that is all choreographed to music.

If WBA is to be adopted in the UK, it is likely that non-critical equipment like lighting will probably use the technology first. Furthermore, it is more likely that wireless networks will be considered in the design and planning stage of the new building rather than in the retrofit scenario. As adoption increases, this will fuel further adoption under both scenarios with increased awareness and understanding of the technology.

Increasingly installation of WBA systems will include CCTV and other security systems. For example:

- In the retail sector Sainsbury endorsed the Vista eclipse 360-degree camera technology provided by Norbain SD. The camera is installed at Watermore Park, Camberley, store to monitor the cash office and automated teller machine room.
- In the hotel and catering sector the refurbishment of Mandeville Hotel near Oxford Street in London involves use of wireless CCTV
- In offices the replacement of Tower 42's old video cassette recorder (VCR) and multiplexer solution with a digital recording suite offers a good example. This includes 5 600GB nine-input DVR units with CD/RW capabilities, as well as new monitors. The system can be accessed by authorised personnel from workstations through the multi-storey building. Also, 40 days worth of images can be stored.
- At airports the new Robin Hood International Airport is protected by 100 Bosch cameras, integrated with access-control/public address systems.
- Special events such as the G8 summit in Gleneagles Hotel involve wireless CCTV. Following the bomb attacks in London, the organisers of the London Olympics have quadrupled their original budget estimate for security measures such as CCTV, facial recognition software to scan the crowds for any known terrorist suspects.

A.7.4 Evolution of demand

Building automation systems have been around for many years in the form of hardwired, independent systems. In recent years, wireless sensors have become economically viable for widespread use in HVAC control appliances. They now cost the same or even less than the conventional wired alternative. Nonetheless, hardwiring of systems would be preferable in buildings that are not typically slated for any foreseeable renovation, or are large permanent structures as it would avoid a massive battery replacement program. Examples of such buildings are factories and warehouses. We therefore focus on commercial office buildings in evaluating the benefits of wireless building automation.

We assume that non-critical systems such as lighting and HVAC will see the wireless technology first. There are still concerns over the reliability and security of the wireless networks for IT, security and access control purposes. No doubt that the benefits we capture for this application also apply to these systems.

Commercial offices

In 2005, the Office of the Deputy Prime Minister (ODPM) published detailed statistics on commercial and industry floor space[108] in the England and Wales. Non-domestic property is classified into four categories:

- Retail premises. Premises that provide 'off-street' good and services to the public. They include supermarkets, corner shops, local post offices, restaurant, cafes, launderettes etc.
- Offices. Offices are classified as purpose-built office buildings, offices over shops, light storage facilities and light industrial activities. Note that larger banks, building societies and post offices containing substantial office space may be included in this class, rather than in the retail class.
- Factories. These range from small workshops to very large manufacturing units.
- Warehouses. These range from small storage units and depots to very large distribution warehouses.

Table A.55 – ODPM office space statistics

	Unknown Age	Pre 1940	1940-70	1971-80	1981-90	1991-2000	2001	2002	2003	All
Number of hereditaments (000)	5.7	163.2	58.5	22.2	38	28.6	3.4	3.5	2.8	325.8
Percent of total	1.70%	50.10%	17.90%	6.80%	11.60%	8.80%	1.00%	1.10%	0.90%	100%
Floor space (000 m^2)	5.8	27.7	18.2	10.9	16.9	14.6	1.7	2.1	1.5	99.4
Percent of total	5.80%	27.90%	18.30%	11.00%	17.10%	14.70%	1.70%	2.10%	1.50%	100%
Average size of hereditament (m^2)	1,015	170	311	492	446	512	504	592	515	305

Since 2000, the number of offices has increased at around 1.9% per annum. Alongside, the total number of floor space has also increased at the same rate, leaving the average size of offices constant over time.

We assume that the current growth rate will continue for the next 20 years. We assume that all new stock will have some form of building automation as previously described. Some, however, may opt for the wireless option.

For the existing stock of commercial offices we consider the proportion that is likely to be refurbished during the forecast period. DTI's 2004 publication "Making the most of our built environment"[109] illustrated the following phases of a building (residential and commercial) life cycle.

[108] ODPM, "Commercial and industrial floor space and rateable value statistics 1998-2004", June 2005

[109] DTI, "Making the most of our built environment. The Sustainable Construction Task Group", March 2004

Table A.56 – Examples of building life cycles

Stage	Periodicity	Description
Refitting	5-15 years	Replacement of energy and water efficient systems and appliances Lower for residential properties
Refurbishment and conversions	15-50 years	Opening up of older buildings to new and multiple users
Regeneration and rebuilding	50+ years	New construction and integrating facilities management

These examples suggest that all offices buildings will be eligible for refit or refurbishment during the forecast period.

Table A.57 – Summary of model assumptions for addressable market

	Low	Medium	High
Commercial offices in 2006 (000 m^2)	104,800	104,800	104,800
Growth rate of office space (%)	1%	1.50%	2%
Life of building automation equipment (years)	20	20	20

Demand scenarios

Measure of demand: Commercial offices with wireless building automation systems.

Wireless building automation systems have been tested and trialled in North America and South East Asia. In the UK, there have been examples testing different aspects of building automation systems, although fully wireless integrated systems are not available in the market. Going forward, developments in standardised equipment and fall in equipment prices, together with pressure for the commercial sector to adopt more energy efficient solutions will drive the take up of WBA systems.

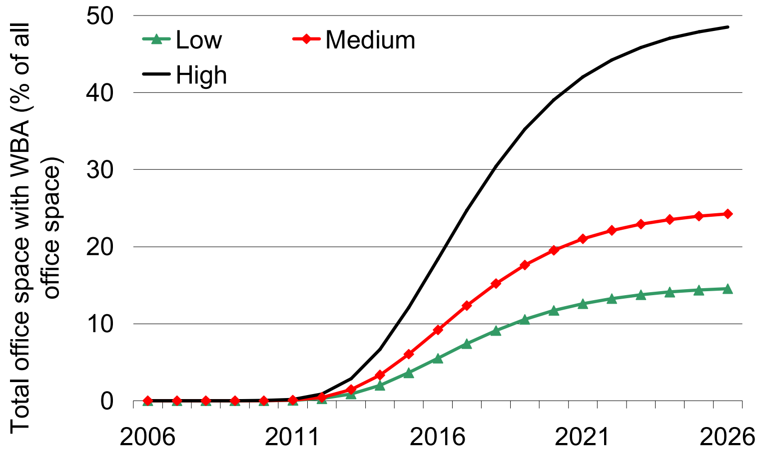
The key assumptions for our three scenarios are set out in Table A.58. We assume that the take up in new commercial buildings and refitted stock is the same. Furthermore, annual installations of WBA include the replacement of existing WBA equipment.

Table A.58 – Summary of model assumptions for adoption of wireless building automation

	Low	Medium	High
% buildings that opt for wireless building automation			
2006	0%	0%	0%
2026	15%	25%	50%
Average growth rate	35%	35%	35%
Time of maximum growth relative to 2006	10	10	10

The resulting take up of wireless building automation under the three scenarios are illustrated as follows.

Figure A.41 – Forecasts of take up of wireless building automation system



A.7.5 Economic value

Counterfactual: Building automation systems remain wired though to 2025.

The cost of wiring a building includes the labour for drilling, digging, installing conduits, and laying cables etc, and depends on complexity, insulation etc required. Using wireless networks may reduce installation costs through less labour and time required to set up system, and maintenance costs through an extensive system of always-on sensors and monitors that improve decision making and maintenance predictability. In various test cases of WBA that have been carried out, the cost of having more wireless equipment is often significantly outweighed by lower installation costs.

Energy consumption from lighting and HVAC both account for almost 30% of total consumption in a typical UK commercial office.[110] The rise in office space, and increased heating, lighting, IT and air conditioning loads in newer buildings have lead to a significant increase in energy consumption in this sector. Recent policy activity in both the UK and Europe is attempting to address non-domestic buildings, promoting and encouraging the adoption of energy efficiency measures. As a result, although existing layout with separate systems for heating, ventilation, lighting, IT, security etc will become more efficient, wireless integrated solutions can bring about additional savings over and above this through the ability to integrate the different systems together could tailor controls to individual occupant needs. We do not consider spill over effects of lower energy consumption, such as reduced carbon emissions and other environmental benefits.

In addition to the energy savings, studies worldwide have shown that the level of occupant dissatisfaction with office environments directly affects their productivity, for example through better ventilation and daylight, although the quantitative effect is not known. Similarly, the value attached to the flexibility with which office buildings can be reconfigured, both in terms of reduced future installation costs and increased asset resale costs, are difficult to quantify.

[110] The Association for the Conservation of Energy, "Energy efficiency in offices: Assessing the situation", 2003

Table A.59 – List of quantified costs and benefits

Benefits	Quantified?	Costs	Quantified?
Reduced cost of installation and maintenance	Yes	Additional costs of WBA equipment compared with wired equipment	Yes
Additional savings on energy consumption for lighting, and heating, ventilation and air conditioning (HVAC)	Yes	Cost of integrating lighting and HVAC with WBA	Yes
Security systems	No		
Reduced carbon emissions due to reduced energy demand	No		
Increased productivity and comfort for building occupants	No		
Increased information on energy and access use of a building	No		
Easier to reconfigure building for new tenant	No		
Increased sale value of property	No		
Benefits of WBA in industrial premises	No		

Installation and maintenance costs

We focus on the electrical installation costs for UK commercial buildings. This covers the installation of fixed electrical wiring and fittings for electrical power, alarms and security systems, and communications equipment. We assume that a proportion of this is directly related to the installation of lighting and HVAC, which excludes the wiring of sockets, placement of fixtures etc. The wireless option reduces a proportion of these costs.

The UK construction industry is changing from one in which clients employ a large number of contractors with specific tasks, to an industry in which a large main leading contractor is commissioned to take prime responsibility. Increasingly they have expanded the scope of their services to include facilities management expertise. The DTI publishes construction statistics in the UK on an annual basis.[111] The latest figures show that total contractors' output[112] in the commercial offices sector increased from £1.8 billion in 1994 to £5.2 billion in 2004, a steady 6.9% per annum. Work done by all electrical wiring and fitting contractors increased from £863 million in 1994 to £2.2 billion in 2004, although this includes all commercial construction such as shops, entertainment complexes, etc.

Commercial offices have been increasing at a rate of around 1.5 million square metres per annum, and account for around 2 per cent of total construction output.[113] Applying this proportion to the total value electrical wiring and fitting carried out, we obtain electrical installation costs of around £15-£35 per square metre. This is around 3.5 to 8 percent of break even rents in London commercial offices of

[111] DTI, "Construction statistical annual. 2005 Edition", February 2006

[112] Contractor's output is defined as the amount chargeable to customers for building and civil engineering work done in the relevant period excluding VAT

[113] Key Note, "Market report 2006. Construction industry", June 2006

around £430 per square metre,[114] and £610 per square meter for top quality space in the City of London. We further assume that around one third of this relates specifically to the installation of lighting and HVAC systems.

The statistics available do not distinguish between new build and refit, so we assume that for cost of electrical installations is the same for the two cases. We also assume that the cost of electrical installation and maintenance continue to rise at 5 per cent per annum, equivalent to the rate of construction growth less the rate of growth of office space.

Wireless building automation has been developed and tested in the United States. The demonstrated cost savings depend on a variety of factors including size of building, location and complexity of work. Examples include:

- Siemens have been developing wireless equipment for BAS and state that a wireless network infrastructure has shown to save "*more than 50 percent when compared to a hard-wired network infrastructure*".[115]
- Pacific Northwest National Laboratory tested wireless sensors and data acquisition for HVAC in commercial buildings as part of the US Department of Energy Office of Building Technology, State and Community Programs.[116] The installation cost for the wireless system was around 30% lower than that of a wired design.

Table A.60 – Summary of model assumptions for installation and maintenance costs

	Low	Medium	High
Lighting and HVAC installation and maintenance cost per square metre in 2006	£5	£10	£15
Growth in lighting and HVAC installation and maintenance cost (%)	5%	5%	5%
% reduction in installation costs from WBA	20%	30%	40%

Energy costs

Between 1973 and 1996 in the UK, energy consumption in commercial sector grew by 65%, reflecting expansion in floor space, and increased heating, lighting, IT and air conditioning loads in individual buildings.[117] In 2004, the commercial office buildings used around 22,500 GWh, of this, 13% was from lighting and 69% from heating and cooling ventilation.[118]

DTI's quarterly publication "Energy trends" showed that the average electricity price in the UK including Climate Change Levy is around 4p/kWh for a medium size office, so the total electricity consumption in offices amounted to £900 million, or around £9 per square metre. Since then non-

114 The Times "Property boss cites 'irrational' optimism about City", 5 September 2006

115 Siemens, "Wireless technology: Networking HVAC controllers can cut installation and labor costs", http://www.us.sbt.siemens.com/customerlounge/whatsnew/press.252.asp

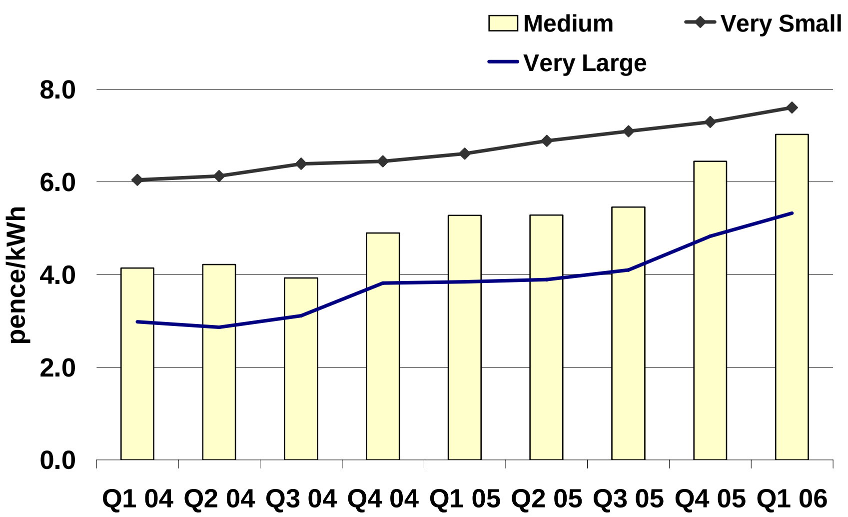
116 Kintner-Meyer M, MR Brambley, TA Carlon, and NN Bauman. "Wireless Sensors: Technology and Cost-Savings for Commercial Buildings" In Teaming for Efficiency: Proceedings, 2002 ACEEE Summer Study on Energy Efficiency in Buildings : Aug. 18-23, 2002, Asilomar Conference Centre, Pacific Grove, California. Vol.7; Information and Electronic Technologies; Promises and Pitfalls., vol. 7, pp. 7.121-7.134. American Council for Energy Efficient Economy , Washington, DC.

117 Scrase, I., (2000) "White-collar CO2", The Association for the Conservation of Energy

118 DTI, (2002), "Energy consumption in the UK", http://www.dti.gov.uk/files/file11250.pdf

domestic electricity prices have risen in real terms, although in 2005 they are still 15% lower than 10 years ago.

Figure A.42 – Average UK non-domestic electricity prices including Climate Change Levy (pence per KWh)



The latest projection of electricity demand in the services sector (both public and commercial) using DTI's UK Energy Model is around 0.6% per annum from 2005 to 2020.[119] Since this rate is below the rate of growth of office space that we have assumed, it implies that overall energy efficiency is improving across all commercial office buildings.

The US Energy Information Administration provides forecasts of energy demand[120] and predict that between 2004 and 2030, petroleum product prices will rise at 0.4% per annum in real terms. Since world oil prices have significant impact on UK energy prices, we will assume that this growth rate feeds through to UK non-domestic electricity prices over the forecast period.

Studies have shown that continuously monitoring building's energy systems can lead to reductions of 10 to 15 percent in total annual energy bills. Franklin + Andrews' Economic Bulletin estimated that the potential savings on running costs from intelligent lighting systems are around 35-45%, and heating systems lower at 10-20%.[121]

[119] DTI, "UK energy and CO2 emissions projections: Updated projections to 2020", February 2006

[120] US Energy Information Administration, Annual Energy Outlook 2006 Supplemental Tables, 2006, http://www.eia.doe.gov/oiaf/aeo/supplement/index.html

[121] Franklin + Andrews, "Economic Bulletin", April 2003. http://www.franklinandrews.com/publications/economicbulletin/

Table A.61 – Summary of model assumptions for energy costs

	Low	Medium	High
Energy demand per square metre in 2006 (KWh/m^2)	220	220	220
Energy cost per KWh in 2006 (pence)	7	7	7
Real growth in energy costs (%)	0.5%	0.5%	0.5%
% of energy cost used for lighting	13%	13%	13%
Lighting cost (£ per m2 per annum)	2	2	2
% additional saving in lighting costs due to WBA	20%	30%	40%
% of energy cost used for HVAC	69%	69%	69%
HVAC cost (£ per m2 per annum)	11	11	11
% additional saving in HVAC costs due to WBA	10%	20%	30%

Termination value

We assume that beyond 2026, the benefits accrued will continue, although they are discounted by the probability that future communications technologies will present an integrated solution to building automation, monitoring and control. We assume this probability to be 10 per cent per annum.

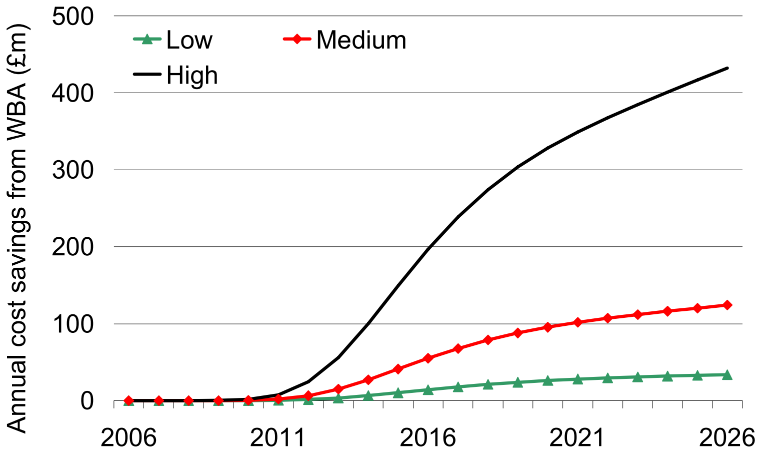
A.7.6 Demand valuation projections

Based on the medium case scenario, the total net present value of wireless building automation is £1.1 billion in 2006 prices.

Table A.62 – Summary of net present value of WBA (£m, 2006 prices)

	Total cost savings from WBA (£m)
Low	312
Medium	1,161
High	4,049

Figure A.43 – Annual cost savings from WBA (£m, 2006 prices)



Detailed forecasts for each of the scenarios are summarised as follows.

Table A.63 – Annual benefits of wireless building automation – Low demand scenario (2006 prices)

	2006	2011	2016	2021	2026
Total office space (Millions m^2)	105	110	116	122	128
Annual installations of WBA (Millions m^2)	0	0	3	2	1
Reduced installation costs (£ per m^2)	1	1.28	1.65	2.12	2.72
Total installation cost savings (£m)	0	0	4	4	3
Total office space with WBA (Millions m^2)	0	0	6	15	19
Lighting cost savings (£ per m^2)	0.4	0.41	0.42	0.43	0.44
Total lighting cost savings (£m)	0	0	3	7	8
HVAC cost savings (£ per m^2)	1.06	1.09	1.12	1.15	1.17
Total HVAC cost savings (£m)	0	0	7	18	22
Total cost savings from WBA (£m)	0	0	14	28	34

Table A.64 – Annual benefits of wireless building automation – Medium demand scenario (2006 prices)

	2006	2011	2016	2021	2026
Total office space (Millions m^2)	105	113	122	131	141
Annual installations of WBA (Millions m^2)	0	0	5	3	3
Reduced installation costs (£ per m^2)	3	3.85	4.95	6.35	8.15
Total installation cost savings (£m)	0	2	23	21	21
Total office space with WBA (Millions m^2)	0	0	11	28	34
Lighting cost savings (£ per m^2)	0.6	0.62	0.63	0.65	0.66
Total lighting cost savings (£m)	0	0	7	18	23
HVAC cost savings (£ per m^2)	2.13	2.18	2.23	2.29	2.35
Total HVAC cost savings (£m)	0	0	25	63	81
Total cost savings from WBA (£m)	0	2	55	102	124

Table A.65 – Annual benefits of wireless building automation – High demand scenario (2006 prices)

	2006	2011	2016	2021	2026
Total office space (Millions m^2)	105	116	128	141	156
Annual installations of WBA (Millions m^2)	0	1	10	7	6
Reduced installation costs (£ per m^2)	6	7.7	9.89	12.7	16.31
Total installation cost savings (£m)	0	7	98	94	98
Total office space with WBA (Millions m^2)	0	0	24	59	76
Lighting cost savings (£ per m^2)	0.8	0.82	0.84	0.86	0.89
Total lighting cost savings (£m)	0	0	20	51	67
HVAC cost savings (£ per m^2)	3.19	3.27	3.35	3.44	3.52
Total HVAC cost savings (£m)	0	1	79	204	267
Total cost savings from WBA (£m)	0	7	197	349	432

A.8 Application 8: Point to point Broadband Fixed Wireless Systems (FWS)

A.8.1 Description of the application

This profile considers point to point broadband fixed wireless systems (FWS) using the unlicensed 71 to 76 GHz and 81 to 86 GHz spectrum bands.

Fixed wireless systems can be used to provide a broad range of new products and applications such as high capacity fixed point to point wireless area networks and broadband internet access which could potentially be used as an alternative or complementary to fibre based solutions. Further applications also include backhaul point to point high speed links for telecommunications operators.

A.8.2 Technical characteristics

Table A.66 summarises the technical characteristics of the bands under consideration (71 to 76 GHz and 81 to 86 GHz) as specified by CEPT and Ofcom respectively.

Table A.66 – Technical characteristics of the bands under consideration (71-76 GHz and 81-86 GHz)

Issue	CEPT	Ofcom
Frequency Band	71-76 GHz and 81-86 GHz	71-76 GHz and 81-86 GHz
Total Bandwidth	2 X 5GHz	2 X 4.75GHz
Number of Channels	1 to 19	Not specified
Channel Bandwidth	250MHz	Not specified
Guard band	125 MHz guard band at the top and bottom of each 5 GHz band	125 MHz guard band at the top and bottom of each 5 GHz band
Maximum E.I.R.P.		+55 dBW

Source: CEPT, Ofcom

Within the examined spectrum bands, potential data speeds currently quoted range from 1Gbps to 10Gbps for short hop (1 to 2km) high availability (more than 99.9%) fixed wireless systems access and infrastructure applications. Currently, such data speeds in the lower microwave bands (4 to 6GHz) are not possible due to bandwidth constraints.

The nature of the propagation in the millimetre wave bands and the possibility of employing highly directional 'pencil beam' signal characteristics mean that applications can be implemented with minimal interference concerns, allowing a potentially highly efficient re-use of the spectrum. In particular the technical characteristics of the FWS that are likely to be deployed are such that multiple users of FWS could co-exist without causing adverse interference, provided there is a registration and self-coordination mechanism in place.

The main features of operating fixed radio systems in the spectrum bands described above can be summarised as follows:

- Availability of wide bandwidths supporting large capacity data rates exceeding those in the lower fixed service bands between 1 and 55GHz, with sufficient bandwidth for terrestrial fixed links to compete or complement fibre optic based access networks
- Fixed service equipment operating at distances of 1 to 2km with high (more than 99.9%) availability
- Possibility of extensive channel re-use, due to the propagation conditions and the highly directional 'pencil beam' signal characteristics which reduce the co-ordination requirements
- Probable use of lower order modulation schemes allowing low cost equipment
- Reduced installation time compared to other methods of broadband delivery. Fixed radio links can often be deployed more quickly than either wired or fibre networks

Requirement for dedicated spectrum

To maximise the opportunities for effective use of the spectrum and keep regulation to a minimum, Ofcom intends to adopt a light licensed process for these bands to enable the authorisation and deployment of point to point FWS in a rapid, self-assigned, self co-ordinated and flexible way.

Ofcom considers that deployment under a licence exempt basis could result in unacceptable interference and would be unlikely to lead to optimal use of the spectrum, particularly considering the high availability applications proposed to be used in the specified spectrum bands. Also, the Ministry of Defence (MoD) has requested that rights to use parts of the specified spectrum bands in the future are maintained. Ofcom therefore considers it necessary that the location of existing terminals is recorded to facilitate co-ordination and to address any future requirements of the MoD. It proposes licensing on a first come first served basis, rather than either licence exemption or release by way of auction.

More specifically, according to Ofcom[122], a simple mechanism to enable individual 70/80GHz links to gain protection from interference can be accomplished by the implementation of a centralised database with a registration system with a first come first served, date and time record essentially forming the basis for this protection. Under this arrangement Ofcom would only become directly involved in managing the co-ordination of links in the spectrum bands in case an interference dispute cases arise.

A.8.3 Evolution of demand

To assess the demand for point to point fixed wireless systems we should consider which end users will require these high data rates (up to 1Gbit/s levels) on an exclusive basis. With few exceptions such end users are likely to be enterprises and, more specifically, large enterprises in that require point to point interconnection between sites less than two miles apart.[123]

Other potential customers include:

- Mobile operators, if and when demand for high data rate mobile services is substantial and demand for increased backhauling capacity is required. This is likely once HSDPA and later HSUPA (3.5G) or even WiMAX are successfully deployed in the market. At the moment, most of the mobile operators have deployed point to point wireless backhaul links in the frequency bands of 11GHz, 25GHz and/or 32GHz, which satisfy their existing requirements of data services' backhauling

[122] http://www.ofcom.org.uk/accessibility/rtfs/consultations/71ghz.rtf

[123] For example BT in London operates many different departments in buildings located less than 2 miles apart

- Service providers who want to provide companies with high bandwidth access to their services
- CCTV applications, especially if they use high definition video images. We have discussed this potential source of demand with industry representatives from the CCTV industry and there appears to be little, if any, demand from this source.

Wireline versus wireless solutions

There is an accelerating move towards use of broadband speeds (e.g. for mobile video, meshed WiFi, IPTV[124], new IT applications, medical imaging etc) and the demand for improved high bandwidth for local access and backhaul is a central issue for telecommunications operators globally.

Operators nowadays have two options for local broadband access and backhaul – wireline and wireless. Both of these options can be further subdivided into lower bandwidth access technologies, and backhaul and higher bandwidth access technologies (e.g. 45Mbps and up).

As far as wireless solutions are concerned there is a need to differentiate between microwave and millimetre technologies. Existing microwave technologies can offer services of up to 155Mbps in a cost efficient way. Above that level, costs for provision of these services rise exponentially and fixed wireless system becomes competitive.

Regarding wireline technologies the only one that can offer very high data speed services with excellent reliability in long distances is the fibre technology (as presented below). However, according to WiFiber[125], a point to point fixed wireless US carrier operating in the 70/80 GHz band, the cost per mile for a new fibre build ranges from $70,000 to $150,000 depending on location.[126] In contrast a 70/80GHz point to point wireless link costs $30,000 per mile regardless of location, and provides the same characteristics of services. This is less than half the cost of the fibre technology solution. This cost is also comparable with that of microwave technologies which provides services with up to 155Mbps of bandwidth. If we then consider that in the U.S, less than 5 per cent of all commercial buildings have fibre[127] and that poor fibre build out is a common problem in other countries as well, we might expect the use of FWS as a fibre extension to grow rapidly.

End users can, for the same cost, experience almost 6 times faster data rates when implementing a 70/80 GHz point to point fixed wireless link than when using microwave links. The drawback for WFS technology is that it is restricted to distances of up to 2 miles. After this repeaters may well required which significantly increase overall implementation costs. In general, it seems that 70/80 GHz wireless solutions offer possibly the best available deal in the market (as measured in £ per Mbps) where end users require short distanced point to point circuits at data speeds higher than 155Mbps.

Besides millimetre FWS, there are two other main technologies capable of supporting high data rate connectivity:

- **Fibre-optic cable**. Fibre-optic cable offers the widest bandwidth of any practical transmission technology, allowing very high data rates to be transmitted over long distances. Thousands of miles of fibre are available worldwide. However, local access remains limited and access can be difficult or impossible due to substantial and often prohibitive up-front costs associated with digging trenches and laying terrestrial fibre. Long provisioning delays are common, due not only to the physical work but also to obstacles caused by environmental impacts and legal implications of the

[124] Also known as "TV over IP", which uses streaming video techniques to deliver scheduled TV programs or video-on-demand (VOD).

[125] http://www.gigabeam.com/admin/WhitePaperManagement/PDFs/WPsGibaBeamWiFibervsothermediaFinalv2.pdf

[126] That is, rural, sub urban, or urban

[127] http://www.stratexnet.com/about_us/news_press/articles_interviews/files/gues82-81.pdf

project. For this reason, many cities around the world now prohibit fibre trenching because of city disruption concerns and risks to architecturally significant or historic buildings and relics.

- **Free space optics**. Free space optic (FSO) technologies employ a laser technology to transmit data to photodiode receivers. Very high data rates of 1 Gigabit per second and beyond can be achieved. Transmissions are drastically affected by fog, where atmospheric absorption can exceed 225 dB/km,[6] resulting in carrier-class 99.999% availability for distances of only a few hundred yards in coastal or fog-prone areas. Because of this serious limitation, some FSO equipment vendors have been bundling their equipment with more robust microwave technology radio links to compensate for this weakness. FSO systems employ complex and costly architectures to overcome the many physics and technology issues of optical transmission. Multiple transmitter lasers are used to minimise blockages of the narrow optical paths by birds, snow, sand, dust or flying debris. Active tracking mounts are used to maintain the precise laser alignment as towers sway or buildings move. Complex cooling systems are required to keep lasers cool and extend lifetimes. Filters are required to minimise optical scintillation effects and deteriorating performance during direct sunlight during sunrise and sunset hours
- **Other high frequency wireless technologies**. As noted earlier mobile operators use radio technologies operating at 11GHz, 25GHz and/or 32GHz to meet their existing requirements for data services backhauling.

Table A.67 presents a comparison of high data rate transmission technologies.[128]

Table A.67 – Comparison table of high data rate transmission technologies

Issue	70/80 GHz	Buried Fibre	Free Space Optics
Data Rates	1Gbps	Virtually unlimited	1 Gbit/s
Typical Link Distances (99.999% availability)	1 Mile	Virtually unlimited	100 Yards
Relative Product Complexity	Low	Low	High
Relative Cost of installation and ownership	Low	High	Low
Installation time	Hours	Months	Hours
Regulatory protection	See Section Figure 1.1:A.8.2	Yes	No

The 70/80GHz wireless solution is very competitive when compared to other technologies that offer similar services. We do not assess every technological option on a stand alone basis. There may also be cases where two options (e.g. 70/80 GHz links and fibre technology) complement each other in order to provide the most efficient and least expensive solution (e.g. in the case where fibre technology is already deployed and an additional 70/80GHz link is required for the 'last access mile').

Enterprises in the UK

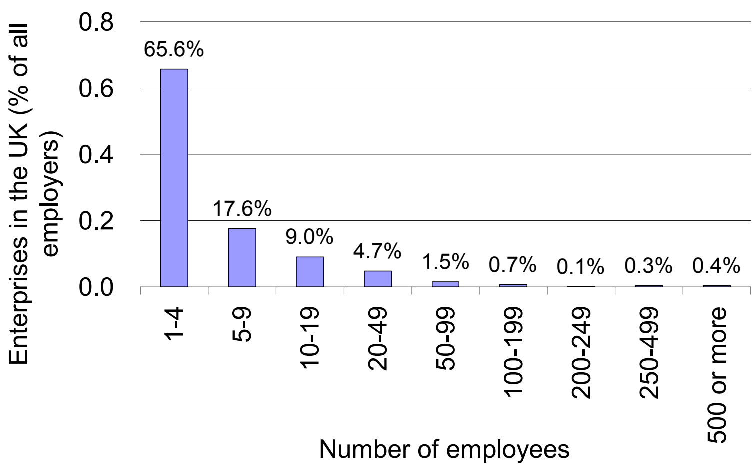
There were an estimated 1.25 million business enterprises in the UK as of 2005.[129] This estimate comprises the private sector (including public corporations and nationalised bodies) and excludes Government and non-profit organisations. Of these, 97 per cent were small (0 to 49 employees), Only

[128] 'Multigigabit wireless technology at 70 GHz,80 GHz and 90 GHz', Jonathan Wells

[129] Excluding sole trader businesses

2.4 per cent were medium sized (50 to 249 employees) and 0.6 per cent were large (250 or more employees) as shown in Figure A.44. Large enterprises make up only 0.6 per cent of the total but they employ 41.5 per cent of the working population of 22 million people.[130] Large enterprises are the ones that might require dedicated point to point very high data rates links in order to satisfy demand for big volumes of high data rate traffic or transfer of information/data between sites that are located in 1 to 2 miles range.

Figure A.44 – Enterprises in the UK



Source: Small Business Service, an agency of the DTI

Demand scenarios

Given the analysis above we conclude that:

- 70/80GHz point to point fixed wireless links provide some competitive advantages compared to other competing technologies for offering the same services. Moreover, 70/80GHz links can be also deployed as complementary to existing solutions
- 70/80GHz point to point fixed wireless links offer the best deal in the market, in terms of £ per Mbps, when short distance point to point high data speed links are required. Typical UK leased circuit prices are:
  - £67,000 per annum for a 2 kilometre 34 Mbit/s link (£33,000 in central London)
  - £187,000 per annum for a 140 Mbit/s link (£98,000 in central London)
- Ofcom plans a 'light license' regime for the spectrum occupied by this application (70/80 GHz band)
- Demand is currently very limited in the UK and will increase only once large enterprises require high data speed links between different sites located within 1 to 2 miles range, or where mobile operators require high bandwidth backhaul links (possibly with the take up of 3.5G or WiMAX)

In developing the demand scenarios we need to consider when large corporations will have a requirement for cheap, short range, high bandwidth (>200Mbit/s) point to point links. Historically demand for bandwidth has increased by an order of magnitude each decade. So at the end of the

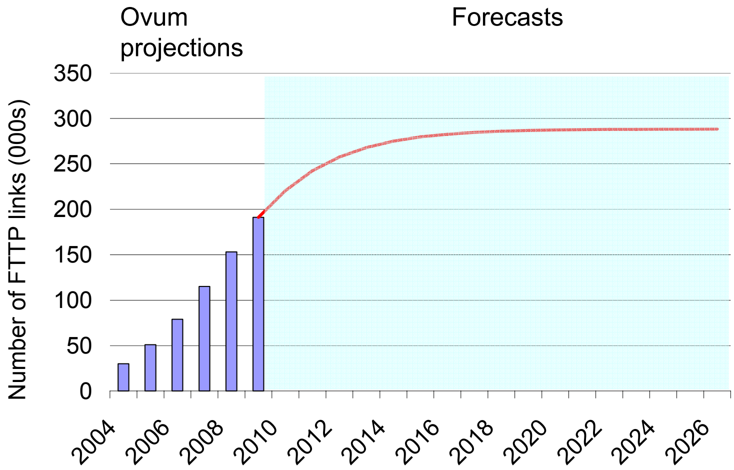
[130] Excludes employees in the public sector

1970s 9.6 kbit/s leased lines were considered as high speed; by the late 1980s this had grown to 2 Mbit/s and today 34 and 140 Mbit/s circuits are considered high speed. Extrapolating this trend we would expect to see demand for FWS technology from large corporations by 2010.

Given this analysis, we use the scenarios set out below as the basis for our projections of demand and economic value

- **High demand scenario**. Demand for FWS links grows to 10% of fibre to the premises (FTTP) connections to enterprises, starting from 2010. This scenario reflects the hypothesis that a small but significant proportion of corporations use FWS as a substitute for fibre, either where fibre build is not cost effective or because speedy deployment is required. We extrapolate the Ovum projections of Figure A.45 as the basis for this demand projection
- **Medium demand scenario**. In the long term 10% of large enterprises (>200 staff) use FWS for interconnecting sites, with three links per enterprise. A further 10% link three of their large sites to their service provider using FWS. We estimate the number of such links in the long term and assume that the number of enterprises remains constant. The move to this position starts in 2010 and follows a Gompertz curve.
- **Low demand scenario**. There is no demand for FWS either because other wireless services substitute for it or because the market does not consider the links reliable enough.

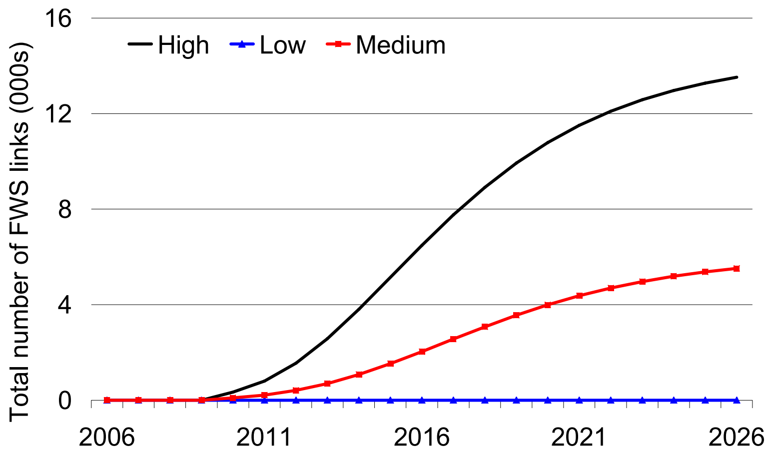
Figure A.45 – Projections of FTTP links



Source: Ovum projections 2006-2009, after 2009, annual growth rate of FTTP links assumed at 65 per cent of previous year.

Figure A.46 shows the demand projections for the total number of FWS links under the three scenarios.

Figure A.46 – FWS demand projections



A.8.4 Economic value

We estimate the incremental economic value of using LE spectrum for FWS links against a counterfactual in which FWS links are not used and service providers and enterprises must rely on other, higher cost technologies or spectrum bands for high speed links and access.

There are two main economic benefits from use of FWS compared with alternative technologies:

- End users with a requirement for high bandwidth access and/or point to point links can purchase them at significantly lower costs (a reduction of up to 75%) than fibre alternatives. There are two effects here. First companies can self provide. At the same time the existence of FWS puts downward pressure on the price of service providers using fibre and other technologies to deliver high speed links and access.
- End users, who would otherwise be restricted to microwave speed links running at up to 155 Mbit/s can use higher speed links and run applications which would otherwise not be possible.

We are not in a position to make a credible projection for the latter benefits. So we focus our quantification on the former benefit as shown in Table A.68.

Table A.68 – List of quantified costs and benefits

Benefits	Quantified?	Costs	Quantified?
Large enterprises use lower cost high capacity links	Yes	Benefit is cost difference	N/a
Availability of FWS links puts competitive pressure on price of links using other technologies	No	None	N/a
End users who are otherwise limited to lower speed links can run new high speed applications	No	Supply of links	No
End users who want high capacity links quickly can use FWS	No	Supply of links	No

We estimate the benefit per FWS link as the difference between the cost of supplying a fibre link and an FWS link as follows:

- An FWS link costs $30,0000 per mile to build while a fibre link costs $120,000 per mile
- The average FWS link is a mile long
- The difference in costs, $90,000 or £50,000 is recovered over a four year period by the supplier
- We assume that the maintenance costs of the two link types are the same
- The cost savings from using FWS rather than fibre is £12,500 per year.

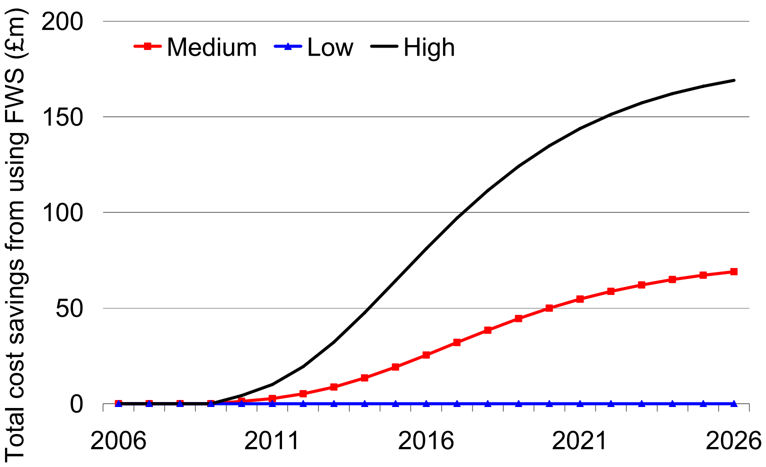
A.8.5 Demand valuation projections

The total net present value of the cost reductions from using FWS links compared to other alternatives are shown in Table A.69.[131] and annual benefit projections are presented in Figure A.47.

Table A.69 – Net present value of using FWS links

Scenario	Net present value (£m)
Low	0
Medium	628
High	1,651

Figure A.47 – The net benefits to from fixed wireless systems



Detailed forecasts of each of the scenarios are given in Table A.70 and Table A.71.

[131] We have calculated the termination value of the net benefit stream in 2026 in the standard way specified earlier

Table A.70 – Annual benefits of fixed wireless systems – Medium demand scenario

Medium scenario	2006	2011	2016	2021	2026
Total number of large enterprises (000s)	10.1	10.1	10.1	10.1	10.1
Percentage of companies with FWS links (%)	0%	1%	5%	8%	9%
FWS links per company	0	0	1	2	3
Percentage of large enterprises with FWS links to service providers	0%	1%	5%	8%	9%
Number of sites per enterprise that are linked to service providers via FWS	0	3	3	3	3
Total number of FWS links (000s)	0.0	0.2	2.0	4.4	5.5
Annual operating cost savings from using FWS (£000)	12.5	12.5	12.5	12.5	12.5
Total cost savings from using FWS (£m)	0	3	25	55	69

Table A.71 – Annual benefits of fixed wireless systems – High demand scenario

High scenario	2006	2011	2016	2021	2026
Total number of FTTP links (000s)	79	242	283	288	288
Percentage of FTTP links that are FWS	0%	0%	2%	4%	5%
Total number of FWS links (000s)	0.0	0.8	6.5	11.5	13.5
Annual operating cost savings from using FWS (£000)	12.5	12.5	12.5	12.5	12.5
Total cost savings from using FWS (£m)	0	10	81	144	169

A.9 Application 9: Telemetry in the utilities sector

A.9.1 Description of the application

What is the application

Telemetry is a technology that allows the remote measurement and reporting of information of interest to the system designer or operator. Both wireless communications (i.e. using a radio frequency system to implement the data link), as well as data transfer over other media, such as dedicated leased lines, telephone or computer networks or optical links that are already in use for telemetry solutions.

It is difficult to define the boundaries of telemetry. They can monitor and control systems over several kilometres, for example across the national grid, but equally are effectively deployed for much shorter in-building monitoring, for example across a few metres for control of machinery.

The definition used here applies to applications used in the utilities for the relay of monitoring and control information between remote equipment and control centres. It excludes applications such as medical telemetry and security alarms. It also explicitly excludes automatic meter reading.

Who are the users?

Industrial telemetry can be applied across many sectors including defence and intelligence gathering, space and resource exploration, security and asset management, vehicle tracking, medicine, retail and vending and a plethora of performance measures and remote management for transportation, irrigation control and pollution monitoring. We focus on the utilities sector. Key applications include:

- Water and Waste Treatment: The water industry uses telemetry at remote pumping stations, for on site monitoring at big sites and, increasingly for monitoring for water flow and leakages. Not only does the water company manage the supply of water, but it also manages the outflow of sewage
- Energy management: the gas industry uses telemetry for similar monitoring of sites, demand and problems with mains gas supply. The electricity industry also uses telemetry to control distribution within the national grid. It also uses the main high voltage cables to send signals.

In many industries, including the utilities, radio telemetry is replacing wired telemetry. For example:

- The rail transport industry in the UK is now replacing track side wired telemetry systems with wireless systems for signalling applications and
- The mining industry is using wireless, through-the-earth, telemetry systems to replace hard-wired systems that are less reliable in emergency situations or if damaged by shifting debris.

Automated Meter Reading (AMR)

AMR is the remote collection of energy consumption data from customers' premises. AMR reduces the operational cost of reading meters. It also allows the energy supply companies to use peak period pricing so as to smooth peak hour demand for energy.[132] Typically AMR involves the use of telemetry.

AMR is already used extensively in the UK by the utilities to manage energy use by major customers e.g. a power station's use of gas or a major factory's use of electricity. There is now a trend towards use of AMR for residential customers:

- The US Energy Policy Act of 2005 promotes residential AMR

[132] This is especially important in the electricity industry

- Sweden recently passed a law requiring AMR for all meters by 2009
- In Italy the state electricity company, ENEL, has converted all 30 million customers to AMR

In the UK Ofgem is keen to see the industry implement AMR in the residential sector[133] while preserving the current competitive industry structure. However, the industry is finding it hard to justify a residential AMR:

- The operational cost savings alone are not sufficient to justify the cost of buying and installing the meter (with costs measured in hundreds of pounds sterling per premise)
- There are concerns about whether Ofgem will allow the capital investment in AMR to be included in the industry's regulated asset base
- There are further concerns about what happens to a retailer's investment in AMR if a customer switches supplier.

Climate change and uncertainty about future sources of energy supply will increase pressure on the companies to introduce residential AMR in the UK. AMR seems inevitable in the long term. At the same time the development is clearly a major one, potentially involving the use of telemetry for 25 million domestic meters.

Our analysis indicates that residential AMR is best treated as a separate application of license exempt spectrum given:

- The major scale of this application
- The high levels of uncertainty attached to when and how quickly residential AMR will grow in the UK when compared to the much more stable demand for telemetry within the utilities own networks and for monitoring demand from major customers.

Given these conclusions we exclude residential AMR from the scope of this profile.

What spectrum is used and how

Telemetry applications and their degree of complexity vary enormously. The main short range device (SRD) bands used for telemetry and telecontrol depend on their application. Typically bands below 1 GHz are used but the 2.4 GHz band is heavily in use by video applications.

Table A.72 lists the LE spectrum bands which are allocated for telemetry use.

[133] This is especially important in the electricity industry

Table A.72 – License exempt spectrum used for telemetry in the UK

License Product	Frequency from	Units	Frequency to	Bandwidth (MHz)
Medical & Biological Applications	0.3	MHz	30	29.7
Medical & Biological Applications	402	MHz	405	3
General Telemetry & Telecommand	433.05	MHz	434.79	1.74
Model Control	458.5	MHz	459.5	1
General Telemetry & Telecommand	2400	MHz	2483.5	83.5
Industrial/Commercial Telemetry & Command	2445	MHz	2455	10
General Telemetry & Telecommand	5725	MHz	5875	150

Of the many bands available only a few are used extensively by the utilities industry:

- There is 1 MHz in the 458 MHz band that was allocated for telemetry and telecommand use in the 1980s following representation from the water industry. It is still used by the water industry but there are also a number of other uses such as control of other utility networks (e.g. electricity and gas), building controls (e.g. fire and security systems) in hospitals and other large sites (e.g. airports, universities) and internal data communications in supermarkets and on other sites. Products were individually designed and developed for these applications.
- Spectrum is also available at 173 MHz (on a non-harmonised basis) but it is not greatly used because the long propagation distances at this frequency range increase the likelihood of interference. The 173 MHz band is mostly used for in-building systems
  Telemetry devices are commonly produced for use in the 433 MHz band

A.9.2 Technical characteristics of WiFi

The wireless bearer technology for telemetry services will vary by specific applications. They include, but are not limited to the following: microwave, Bluetooth, GSM-based technologies and IP over GPRS or SMS.

The wireless portion will need to interface with a variety of proprietary and public infrastructures including: PSTN, xDSL and enterprises VPNs. The industry is also reviewing the possibility of using WiMAX as part of future telemetry infrastructure.

Harmonisation of spectrum bands

According to a study for Ofcom by Indepen and Aegis Systems[134] there is little demand for harmonisation of spectrum for telemetry by the utilities. In the UK for example there are a number of relatively small UK manufacturers making equipment for the UK and overseas markets at a cost of around £550 per unit in the 458 MHz band.[135] While this is much more expensive than equipment at 433 MHz, which costs around £5, the utilities are willing to pay considerably more for a product that meets their specific requirements.

[134] Indepen and Aegis Systems, "Costs and benefits of relaxing international frequency harmonisation and radio standards", March 2004

[135] Equipment can be adapted to other bands at relatively low cost because only two components in the RF part of the equipment need to be changed.

A.9.3 Evolution of demand

Industrial telemetry and telecontrol is a well-established application. Demand has been stable and there is little market growth in the sector at present. Equipment suppliers are optimistic that demand for telemetry in the utilities sector will grow significantly over the next few years. This optimism is largely driven by the expectation that AMR will move to wireless rapidly and have a knock on to AMI. Growth drivers include:

- The significant reductions in the costs of data collection and improvements in operational efficiency which telemetry can bring;
- The signing into law of the US Energy Policy Act of 2005 by President Bush which will promote the need for accurate monitoring. On World Report: Wireless AMR & Submetering: A Market Dynamics Study on Fixed Wireless Technologies estimates that by 2008 there will be 130 million AMR telemetry devices installed in the US; 80 million will use wireless technologies. The same study also claims that wireless networking will drive adoption of advanced AMR that will reduce water, gas and electricity costs by up to 25%.
- Some European and Asian utilities are making a strong commitment to more automation. For example Sweden passed a law recently to require AMR for all meters by 2009. Wireless will doubtless support the need for such rapid deployment.

As previously noted, demand for industrial telemetry has been stable for some time. Consequently we have found very few market estimates or projections for anything other than AMR adoption with the following exceptions:

- The ECC PT43 report estimates that the turnover of the wireless telemetry industry in the EEA is about €1,000 million per annum.
- In their study, Indepen and Aegis estimated that there were 25,000 radio telemetry systems used by UK utilities for critical communications. The typical system consisted of a master station and 5 outstations. Replacing the radio links between these stations with fixed links would, over a 5 year period, generate additional costs of £4.1 billion.

Drivers and barriers

Availability of LE spectrum is not a barrier to the adoption of wireless telemetry. The key barrier is the cost of installation and implementation of wireless capable equipment and the relevant supporting back-office systems. Anglian Water for example manages the water supply to the UK's driest region.[136] It is evaluating microwave as part of its infrastructure to monitor water flow and link in with its alarm systems. However this is a medium to long term project.

Wireless simplifies installation and operation. It removes the need for complicated wiring. It also allows the utility to own the whole system with no third party carrier requirements. Finally, equipment suppliers in this field claim that wireless costs compare favourably with substitute technologies.

Substitutes

There are two main substitutes to wireless telemetry in the utilities sector:

- The main alternative at the moment is manual execution: A member of the public or local council reports a leak; the utility sends staff to the site to assess the situation and action the solution.

[136] Anglian Water has installed fixed water meters to around 2.7 million, or 50% of households in their region. This is higher than any other region in the UK, and the programme has been in operation since the mid 1990s.

There may be a limit to amount of sites a dedicated team can attend in one day and they require transport to each site.

- Wireless or radio telemetry can be substituted by cabled telemetry or leased lines. Table A.73 summarises some of the advantage of wireless telemetry. These advantages are considerable and wireless rather than cable telemetry is used extensively by utilities as a result.

Technologies such as GSM/GPRS and 3G are also considered for telemetry and telematics applications because the commercial network infrastructure already exists. Whilst these technologies sometimes offer an appropriate solution, they have not been optimised for the specific telemetry application under consideration. The power consumption, terminal equipment cost, data transport cost and/or data rate are unlikely to all be optimal for any given application.

Other lower power wireless data transfer solutions such as Bluetooth, DECT or 802.11b WLAN may offer more attractive cost models but usually fall short in other ways such as achievable range or battery life.

Table A.73 – Advantages of wireless telemetry over fixed telemetry

Radio Telemetry	Cabled Telemetry
Able to operate from moving objects	Not possible in most cases
Able to cross rivers, roads, hills and mountains	Only at considerable cost and over a long period
Resilient to lightning due to small size and single earth point. Or in many case a totally floating, earth independent system	Problematic due to long cable runs prone to induced voltages from nearby strikes or strokes
Electrical isolation between systems	Isolation is costly and usually limited to 1500V maximum
Easily expandable media	Not easy to splice in extra stations onto old networks
Easy to move or re-locate	Difficult to move
Ideal for clean room environments	Not ideal as requires drilling etc generating dust
Suitable for installations where cables must be unobtrusive due to environmental or health and safety requirements	Cables are considered unacceptable in certain locations

Demand scenarios

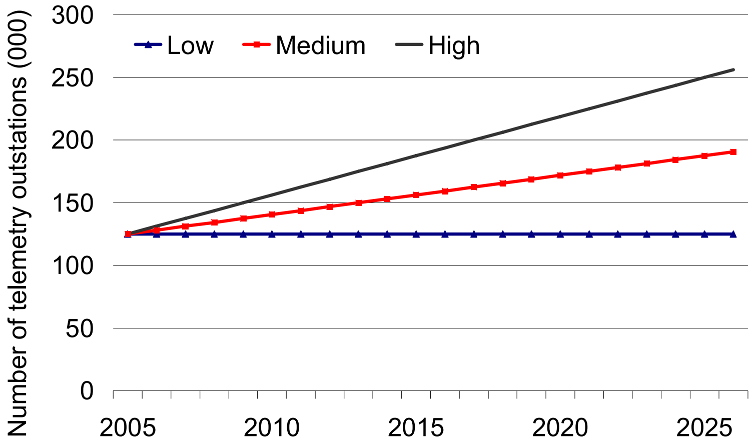
Measure of demand: Number of telemetry outstations.

We propose the following demand scenarios, noting that residential automated meter reading is excluded from the evaluation:

- Low demand scenario: demand for radio telemetry remains at its current level (as indicated above)
- High demand scenario: demand for radio telemetry within the utilities doubles from current levels by 2026 in response to a need for better management of resources
- Medium demand scenario: midway between the high and low demand scenarios.

We use as our measure of demand the number of radio telemetry links. Table A.48 presents our projections of demand for these three scenarios.

Figure A.48 – Demand for radio telemetry links



A.9.4 Economic value

Counterfactual: The use of telemetry is not adopted by the utilities in the UK

In making an economic assessment of the value of radio telemetry we use as our counterfactual a scenario in which telemetry systems do not used wireless technology. Instead they use wired technologies or disappear. Table A.74 lists the costs and benefits which we quantify.

Table A.74 – List of quantified costs and benefits

Benefits	Quantified?	Costs	Quantified?
Cost savings for utilities when	Yes	Cost of telemetry units	Yes
Easier to reconfigure and expand number of monitoring stations	No	Benefit is cost difference	N/a
Lower environmental impact	No	Benefit is cost difference	N/a

Use of radio telemetry systems by utilities generates economic value in four main ways:

- Lower operating and staff costs. Automatic monitoring reduces the need to recruit and employ field staff. Wireless monitoring and control also increases operational efficiency by providing frequent, real time statistics. In most cases radio telemetry is very much cheaper than fixed link telemetry
- Timely fault management. For the water industry for example there is a benefit in being able to measure water flow and pressure to locate burst pipes. With the prospect of climate change reducing water reserves as demand increases, managing water supplies and minimising waste will be increasingly important.
- Manage supply contracts more effectively. Telemetry-based data collection allows the utility to estimate usage on a daily or hourly basis and thereby advance purchase their supply at wholesale rates. The alternative is meeting extreme peak demand by purchasing additional power on the high cost spot market or investing in an over-specified infrastructure to handle peak demand for a fraction of the time.

- Manage demand profiles. An automated metering infrastructure (AMI) provides utilities with a mechanism to manage the over-demand periods by reducing consumption and "flattening the top" of the demand curve by reducing or shifting peak demand, rather than increasing production.

A.9.5 Economic valuation projections

For the quantification we assume that:

- The benefits of telemetry listed above are substantial and would result in current levels of demand for telemetry, even if radio was not available and leased lines were required instead
- The net benefit of radio telemetry lies in the costs savings it generates relative to using leased lines to provide the telemetry links
- If the utilities had to use leased lines they would rent Kilostream circuits from BT. These offer data speeds of up to 19.2 k/bit/s
- The average link is 15 kilometres in length
- The cost of installing radio equipment is the same as the up front connection charge for BT leased lines.

Using these assumptions we make the projections of Table A.49 for the net benefits of radio telemetry to the UK. Table A.75 tabulates the net present values of these net benefit streams.

Figure A.49 – Annual benefits of radio telemetry

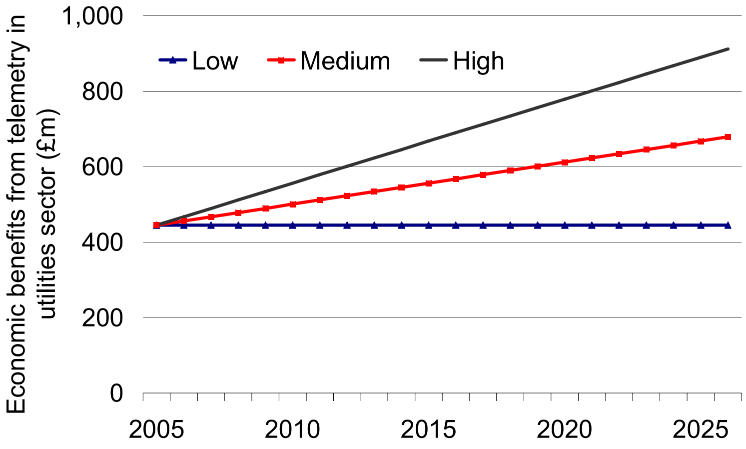


Table A.75 – Total net present value of the wireless telemetry in the utilities sector – 2006 to 2025

Scenario	Net present value (£ billion)
Low demand	8
Medium demand	10
High demand	13

A.10 Application 10: Wireless home alarms

A.10.1 Description of the application

This profile considers demand for and the economic value of domestic wireless alarm systems in the UK. There are two types of security systems for the home:

- Burglar alarm systems that use audible and visual signalling only, i.e. external siren and strobe, and are not connected to any monitoring station. They are dependent on neighbours or passers by hearing the alarm ringing and raising the alarm. The police regulation DD243 stipulates that a single tripped sensor from a burglar alarm is no longer enough to prompt a police response. Either a break-in has to be confirmed by sight or sound, or two alarm sensors need to be triggered before the police will do anything.
- Monitored alarms, on the other hand, are connected to one of several specialist Central Monitoring Stations (CMS) through the phone line which are run by security companies like ADT. As soon as the alarm is triggered in one zone of the house the bells are automatically sounded and a signal is sent along a telephone line to the monitoring station. If a second sensor is then triggered, indicating that there is movement within the house, the home owner and any key holders are automatically contacted by phone. If these people are unable to explain why the alarm has been triggered then the police will be called.

Wireless alarm systems are currently available to buy, and there is online guidance on how to install such systems. Other firms offer bundled services of installation and equipment. Wired options are also available, and are typically installed in conjunction with monitored systems. Historically, wireless systems have proved to be more prone to technical problems and false alarms than wired systems, not to mention the problem of replacing batteries. Some statistics show that the percentage of false alarm calls caused by either equipment, communication or user error represented in excess of 92% of all alarm activations in the UK.[137] The installation of fully hardwired systems usually minimises interference and false alarms, with wiring monitored against tampering. Nonetheless, wire free door contacts, motion sensors and smoke detectors are now available and can be added to existing systems.

Figure A.50 shows the general set up of a home alarm system and the devices that are currently available in the market:

- A control panel integrates the security, control and automation systems within the home, with different combinations of detection devices.
- The door contacts are designed primarily for protecting doors and windows using a built-in magnetic contact that operates in conjunction with a magnet to detect the opening and closure of a door or window.
- Key fob and key pad transmitters are designed for arming and disarming the security systems, and for emergency signalling, access control, home automation and remote control applications
- A variety of sensors which, in wireless based systems, use LE spectrum to communicate with the control panel and which include:
  - Passive infra-red detectors (PIRs) detect motion of an infrared emitting source, usually a human body. An intruder entering the protected area is detected when the infrared energy

[137] http://www.psni.police.uk/index/crime_prevention/property___homes/pg_crim_pre_security_alarms.htm

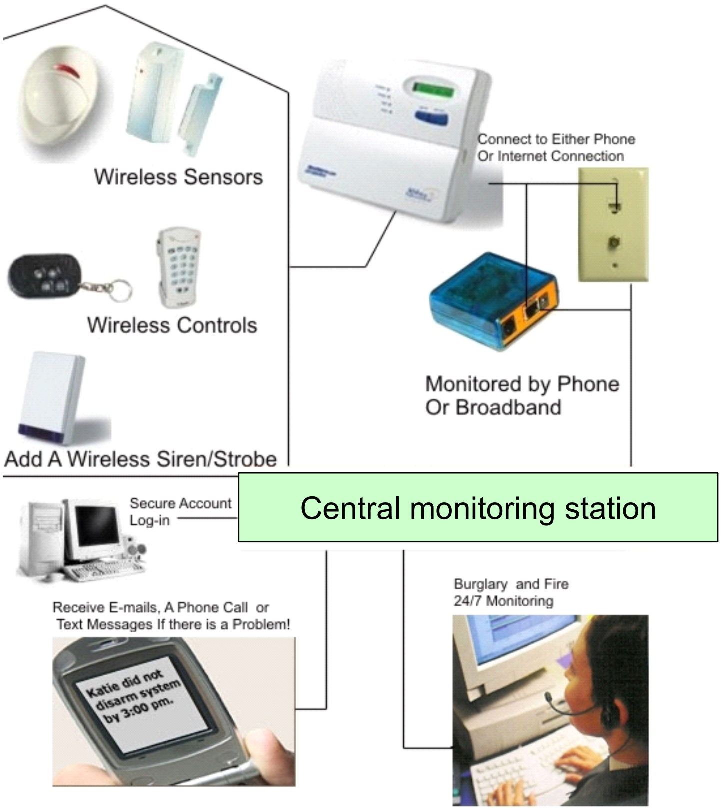
emitted from his body differs from a previously much cooler part of the protected area, which activates the alarm.

- Smoke, gas and flood detectors
- Wrist and pendant transmitters (panic alarms) for the elderly
- Valuable art protection, e.g. tilt detectors
- Glass break detectors

- Home monitoring system, typically through an internet-based account that provides a full log of all communications made by the control panel. It can list events that have occurred in the monitored property in real-time, and provide reminder and status messages regarding low batteries, and power cut etc.

These devices are available in several optional frequencies in compliance with European, US and other international standards. Each transmitter is powered by a standard long-life battery, which is constant monitored, with automatic reporting to a receiver when the battery needs to be replaced.

Figure A.50 – Typical components of a home alarm system



A.10.2 Technical characteristics

Based on the BT Home Monitor VP1000 system[138], the technical characteristics of the devices are as shown in Table A.76. It is also possible that Doppler microwave sensors[139] are used to complement

[138] http://www.shop.bt.com/invt/cbv103

[139] The microwave sensor sends out a high frequency sound wave while listening for bounce back. When the sound wave is returned at a different frequency the sensor knows that there is a moving object within the detection zone. It then sends a signal to the internal relay, which is wired to the door control's activation input.

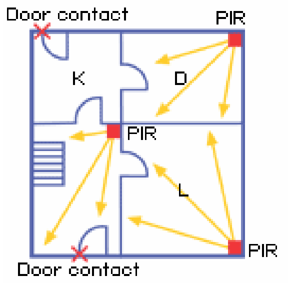
passive infrared sensors. These operate mainly at 10 GHz with some at 24 GHz. The ECC PT43 report estimates that around 25% of home alarm systems use Doppler microwave sensors. Alarm systems now make increasing use of CCTV. But so far such use is confined to the commercial sector. Home use of CCTV for security purposes is still relatively rare.

Table A.76 – Some technical characteristics of wireless home alarm devices

Device	Operating frequency	Battery life	Overall message length	Coverage range
Control panel	868.95MHz	Wired, with backup battery for up to 8 hours		
Magnetic door contact	868.95MHz	2.5 years	36 bits	
Movement detectors using Passive Infrared (PIR)	868.95MHz	2.5 years	36 bits	12m x 12m, 90^0, some with pet tolerance
Key fob	868.95MHz	1 year		

The general setup within the home does not require long distance propagation, since each room would be fitted with one or more device as shown in Figure A.51.

Figure A.51 – Typical installation in a two bedroom home



A.10.3 Evolution of demand

The increased take up of home alarm systems will be driven by a number of factors, including:

- Perception of likelihood of burglary in the area
- Lower home contents insurance premiums
- The rate of take up of alarm systems in new homes where alarm systems are often built in from the start
- Availability of simple, cost effective solutions

There are two broad categories of households that will use home wireless alarm systems:

- Those who fit an alarm system regardless of future development of wireless systems
- Those who fit only a wireless home system and would not consider a wired system

Developers in the home-build sector face similar choices: depending on the overall demand growth for home alarms, they will install the most cost effective system, whether it is wired along with other electrical wires, or wireless that can be tailored to home buyers' preferences.

Household growth

There are 24.2 million households in Great Britain in 2005[140] and 660,900 in Northern Ireland in 2005[141]. This will grow to 25.7 million in England[142], 2.5 million in Scotland[143], 1.471 million in Wales[144] and 815,500 in Northern Ireland[4] by 2025[145]. This equates to a household growth rate of approximately 1.1% per annum for the UK as a whole.

The number of dwellings in the UK is 25.9 million in 2004.[146]. Permanent household dwellings completed in the UK by private enterprises have been increasing at steadily since 1999 at around 3.0% per annum from 152,857 to 182,691.[147] Dwellings completed by registered social landlords (RSLs) have remained fairly constant over this period whilst dwellings completed by local authorities have fallen from 881 to 131. We assume that, in the new build sector, the most likely candidates to take up home security systems are those built by private companies. Although recent history shows that the rate of growth in new build dwellings has outstripped the rate of household growth, we assume that future supply will grow at a lower rate of 1.5% per annum.

Demand scenarios

Measure of demand: Number. of wireless home alarm systems in stalled. Table A.77 presents the three demand scenarios for the take up of wireless home alarms

Key Note[148] found that since 1997 there has been an upward trend for professionally fitted burglar alarms, smoke alarms and outside security lights. There are different estimates of the extent to which homes in the UK are fitted with security alarms. The British Security Industry Association (BSIA) estimates that total household penetration of alarms at 12% yet others estimate this at around 20%. We will assume that 15% of households are currently equipped with alarm systems.

Key Note forecast that the UK market for electronic security systems (both businesses and residential) is likely to grow by around 2% per annum to 2008. In the residential market, growth will likely to be gradual. It is not likely to be very easy to persuade people to part with the money needed to have a system professionally installed, maintained and monitored, unless they live in a particularly high-risk area or are fairly wealthy. Incentives and pressures from the insurance industry could help, but any discounts on insurance need to be very attractive to offset the cost of installing an alarm system. The nuisance caused by false alarms also deters potential customers.

We assume that currently around 25% of all residential security alarms use wireless rather than wired technology to convey information from the sensors to the control panel. We assume that demand for wireless alarm systems grow on a straight line basis between 2006 and 2025. This is a reasonable simplifying assumption given the current modest growth rates in the installed base of home alarms.

140 Table 2.1, ONS (2006) Social Trends 36

141 Household projections, Northern Ireland Statistics and Research Agency, http://www.nisra.gov.uk

142 http://www.communities.gov.uk/index.asp?id=1002882&PressNoticeID=2097

143 http://www.gro-scotland.gov.uk/statistics/library/household-estimates-projections/index.html

144 http://www.wales.gov.uk/keypubstatisticsforwales/content/publication/housing/2006/sdr30-2006/sdr30-2006.pdf

145 http://www.communities.gov.uk/index.asp?id=1002882&PressNoticeID=2097

146 Figure 10.1, ONS (2006) Social Trends 36

147 ONS and ODPM, Housing Statistics 2005, December 2005, http://www.communities.gov.uk/pub/591/HousingStatistics2005PDF1342Kb_id1162591.pdf

148 Key Note, "Security Industry Market Review", September 2004

Given these considerations we set out our proposed demand scenarios for wireless home alarms in Table A.77.

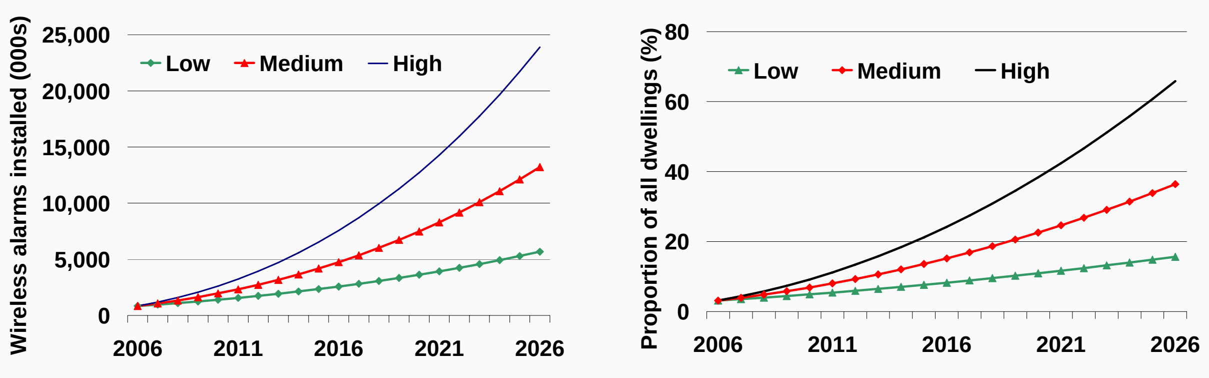
Table A.77– Demand scenarios for wireless home alarms

	2006	2026			Comments
Scenario		**Low**	**Medium**	**High**	
Dwellings in the UK (Millions)	26.9	36.3	36.3	36.3	
Growth of new dwellings built in the UK		1.5%	1.5%	1.5%	
Existing stock					
% dwellings with alarm systems	15%	30%	50%	70%	
% of that are with wireless alarms	20%	40%	60%	80%	Assume a substantial increase in the percentage of wireless alarms for households in existing buildings in future given easier installation of wireless rather than wired systems
Total percentage of wireless alarm systems	3%	12%	30%	56%	= % dwellings with alarms * % of these that are wireless
Implied annual growth rate of wireless take up		8%	13%	16%	= Average growth of wireless alarms between 2006-2026
% of wireless alarms installed because of availability	80%	80%	80%	80%	Assumes that bulk of new alarm systems in existing buildings would not be installed if wired systems were the only choice
New stock					
% new build dwellings installed with alarm systems	30%	50%	70%	90%	Assumes new build households are more likely to be alarmed than existing buildings
% of these with wireless alarms	30%	50%	75%	100%	Assume percentage of wired alarms higher in new build where installation costs for wired systems are lower
Total percentage of wireless alarm systems	9%	25%	53%	90%	= % dwellings with alarms * % of these that are wireless
Implied annual growth rate		7%	10%	13%	= Average growth of wireless alarms between 2006-2026
% of wireless alarms installed only because it is available	40%	40%	40%	40%	Assume that substantial percentage would still be installed if wired systems were the only choice

Figure A.52 illustrates the outcome of these demand scenarios.

Figure A.52 –Take up of wireless home alarms

Total number of wireless alarms installed (000s)	Proportion of all dwellings that have installed wireless home alarms (%)



A.10.4 Economic value

Valuation scenarios

Counterfactual: Wired systems only are used in UK homes

Table A.78– List of quantified costs and benefits

Benefits	Quantified?	Costs	Quantified?
Where wireless alarms substitute for wired systems			
Reduced cost of installation	**Yes**	**Additional cost of wireless system**	**Yes**
Improved appearance of house with no wires	**No**		
Easier to add and reconfigure system than with wired system	**No**		
Where wireless systems are installed and wired systems are not acceptable			
Reduced probability of burglary	**Yes**	**Cost of wireless system**	**Yes**
Termination value			
Benefits of fitting wireless home alarms accruing beyond 2026	**Yes**		

We propose to quantify the two main economic benefits from the installation of wireless home alarm systems:

- Households which are prepared to use a wired system but choose a wireless system enjoy the benefit of one-off lower installation costs. These households do not enjoy the benefit of a lower risk of burglary. In the absence of wireless systems this group would choose a wired system and enjoy this benefit anyway.

- Households which would only install a wireless system do not get the benefit of lower installation costs but do enjoy the benefit of a lower risk of burglary coupled with lower insurance premiums.

Reduced installation costs

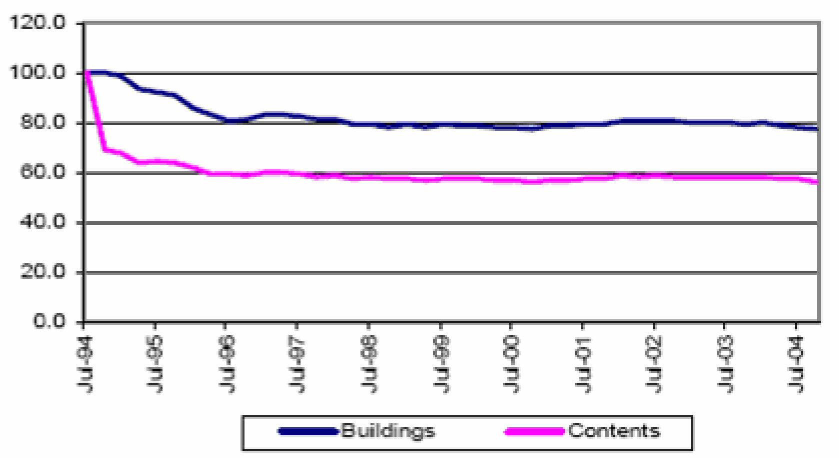
The cost of installing a full wired option is around £500 (with around £200 to £300 in addition for monitored systems).[149] There are also many companies installing wireless systems from £300 upwards, more for the number of wireless devices that are connected to the control box. There are many off-the-shelf security systems that are available from DIY stores and local high street shops. These are available in wired and now wireless versions. The advantage of wireless systems is that they are generally much easier to fit. However, on the downside they are less suitable for advanced security applications, like remote video monitoring. We assume that, on average, installing a wireless rather than a wired system reduces installation costs by £200.

Reduced risk of burglary

According to industry statistics,[150] every 37 seconds a home somewhere in Britain is burgled, and every year there are 1 million burglaries and attempted burglaries. Typical houses that are targeted are ones without visible signs of security, such as security lighting or alarm bell boxes. British Crime Survey statistics show that such devices are effective in reducing the risk of burglary.

The ABI General Insurance Monthly[151] showed that 77% of UK households took out home contents insurance in 2005, with an average annual premium of £159, and in recent years, theft claims have fallen as unemployment and burglary numbers have fallen. In general, household premiums have remained stable over the last decade, as shown by the AA Household Premium Index in Figure A.53.

Figure A.53 – The AA Household insurance premium index, 2000 prices



Source: ABI General Insurance Monthly, December 2004, http://www.abi.org.uk/Display/File/Child/548/December_2004.pdf

[149] http://www.bbc.co.uk/crime/prevention/alarms.shtml

[150] http://www.secureone.co.uk/domesticalarms/burglaryfacts.html

[151] http://www.abi.org.uk/Display/File/Child/548/December_2004.pdf

The new PD6662 legislative regulation in the UK applies to all alarm systems installed after 1 October 2005. It introduced a grading system whereby the security risks of the premises need to be assessed and a particular grade of alarm recommended. The grades are based on criteria supplied by the insurance industry.

The lowest Grade is grade 1, and DIY alarms fall into this category. Insurance companies may or may not recognise these alarms for security and discount purposes. Professionally installed and maintained police monitored alarms are classed as Grade 2, and this will apply to the majority of residential and commercial premises. Grade 3 alarms require a higher level of diagnostic monitoring (to detect tampering) and have a built-in mobile phone so it can still summon the police even if the phone line is cut. Grade 4 alarms are the highest security and apply to banks etc.

The average value of a theft claim was £1,250 in 2005. The Home Office published an updated report on "The economic and social costs of crime against individuals and households 2003/04"[152] and estimated that the total costs as a consequence of burglary in a dwelling were £3,268, of which £1,011 were associated with loss and damage of property. It also takes into account the expenditure on security in anticipation to such crimes, such as home alarms. This study updates the previous Home Office study[153], particularly in the methodology used for estimating the costs associated with the criminal justice system. Comparison of these estimates show that the costs of burglaries have increased by over 5% per annum between 2000 and 2004.

[152] Dubourg, R. and Hamed, J., "Estimates of the economic and social costs of crime in England and Wales: Costs of crime against individuals and households, 2003/04", Economics and Resource Analysis Research, Home Office, June 2005.

[153] Brand, S. and Price, R., "The economic and social costs of crime", Home Office Research Study 217, 2000

Table A.79– Costs of burglaries in the UK (£ per burglary, 2004 prices)

	Costs in 2004/05
In anticipation of crime	
Security expenditure	221
Insurance administration	177
Consequence of crime	
Physical and emotional impact on direct victims	646
Value of property stolen	
Property damaged / destroyed	846
Property recovered	187
Victim services	-22
Lost output	11
Health services	64
In response to crime	
Criminal justice system	1,137
Total	**3,268**

Installing an alarm system reduces the risk of burglary and this creates an economic benefit.[154] Using the Home Office estimates, we deduct the security expenditure from the total and adjust it by inflation to 2006 prices. This gives the costs to households as a result of being burgled. However, to enjoy the annual benefits of reduced burglary, there is a one off cost of installation, which we assume is £300. This cost remains constant over time, so that the lower costs of equipments are offset by choosing more sophisticated components.

[154] As commonly adopted in cost benefit analyses, we exclude the black economy from consideration, so that the loss of a possession results in a reduction in benefits to society, i.e. that same good does not generate a benefit to the burglar.

Table A.80– Assumptions on reduced risk of burglary

	2006	Low	Medium	High
Costs of household burglary in 2006 prices	£3,200			
Growth in costs of burglary		1%	3%	5%
Risk of burglary per household per annum		5%	5%	5%
Reduction in probability of being burgled by fitting home alarms		30%	50%	70%
Reduction in risk of burglary after fitting home alarm		1.5%	2.5%	3.5%
Cost of installing wireless home alarms in 2006 prices	£300			

The annual benefit from fitting a home alarm system is therefore

Cost of burglary * Probability of burglary * Reduced risk of burglary

In 2006, this is equivalent to £80 per annum for a household that fits a wireless home alarm system who would not have considered the wired option based on the medium case scenario.

Termination value

We estimate the benefits over 20 years to 2026. Beyond this period, we believe that new technology will develop and an alternative, superior solution would be available. To capture this we assume that the benefits accrued in 2026 will continue, although they are reduced each year by 10 per cent reflecting the increasing probability of a surpassing technology.

A.10.5 Demand valuation projections

Based on the medium case scenario, we estimate that the total net benefits of wireless home alarms using licence exempt spectrum is £2.4 billion in 2006 prices.

Table A.81– Total net present value of benefits (£m, 2006 prices)

Scenario	Total net present value of benefits (£m, 2006 prices)
Low	621
Medium	2392
High	6432

Detailed calculations for each of the scenarios are summarised in the subsequent figure and tables.

Figure A.54 – Annual benefits of wireless home alarms (£m, 2006 prices)

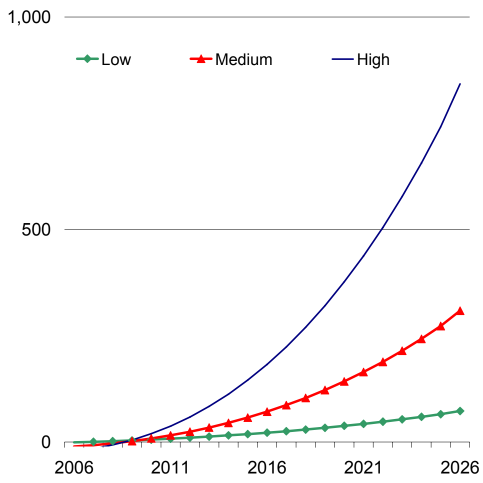


Table A.82– Annual benefits of wireless home alarms – Low demand scenario (2006 prices)

Low	2006	2011	2016	2021	2026
Total number of wireless alarms installed (000s)	844	1,571	2,588	3,949	5,718
Number of wireless alarms installed in preference to wired per annum (000s)	42	66	96	134	114
Reduced cost of wireless installation per system (£)	200	200	200	200	200
Benefits from reduced installed costs (£m)	8	13	19	27	23
Number of wireless alarms installed because of wireless per annum (000s)	83	113	146	185	55
Installation cost (£)	-300	-300	-300	-300	-300
Costs of installing wireless home alarms (£m)	-25	-34	-44	-55	-55
Total number of wireless alarms installed because of wireless (000s)	660	1,133	1,761	2,568	3,578
Cost of burglary (£)	3,200	3,364	3,537	3,718	3,908
Reduction in risk of burglary after fitting home alarm (%)	0.8%	0.8%	0.8%	0.8%	0.8%
Benefits from reduced risk of burglary (£m)	16	29	47	72	105
Total net benefits per annum (£m)	-1	8	22	43	73

Table A.83– Annual benefits of wireless home alarms – Medium demand scenario (2006 prices)

Medium	2006	2011	2016	2021	2026
Total number of wireless alarms installed (Millions)	844	2,335	4,764	8,339	13,299
Number of wireless alarms installed in preference to wired per annum (Millions)	66	131	221	337	281
Reduced cost of wireless installation per system (£)	200	200	200	200	200
Benefits from reduced installed costs (£m)	13	26	44	67	56
Number of wireless alarms installed because of wireless per annum (000s)	167	273	396	536	115
Installation cost (£)	-300	-300	-300	-300	-300
Costs of installing wireless home alarms (£m)	-50	-82	-119	-161	-165
Number of wireless alarms installed because of wireless (Millions)	660	1,700	3,304	5,555	8,548
Cost of burglary (£)	3,200	3,364	3,537	3,718	3,908
Reduction in risk of burglary after fitting home alarm (%)	1.3%	1.3%	1.3%	1.3%	1.3%
Benefits from reduced risk of burglary (£m)	26	72	146	258	418
Total net benefits per annum (£m)	-10	16	72	165	309

Table A.84– Annual benefits of wireless home alarms – High demand scenario (2006 prices)

High	2006	2011	2016	2021	2026
Total number of wireless alarms installed (Millions)	844	3,248	7,598	14,350	24,028
Number of wireless alarms installed in preference to wired per annum (Millions)	91	215	391	627	523
Reduced cost of wireless installation per system (£)	200	200	200	200	200
Benefits from reduced installed costs (£m)	18	43	78	125	105
Number of wireless alarms installed because of wireless per annum (000s)	255	486	751	1,056	198
Installation cost (£)	-300	-300	-300	-300	-300
Costs of installing wireless home alarms (£m)	-76	-146	-225	-317	-332
Number of wireless alarms installed because of wireless (Millions)	660	2,382	5,326	9,674	15,637
Cost of burglary (£)	3,200	3,364	3,537	3,718	3,908
Reduction in risk of burglary after fitting home alarm (%)	1.8%	1.8%	1.8%	1.8%	1.8%
Benefits from reduced risk of burglary (£m)	37	140	330	629	1,070
Total net benefits per annum (£m)	-21	38	183	438	843

Appendix B: Using Gompertz curves for projecting demand

This section sets out some useful formulae for using the Gompertz curve for projecting demand for products and services.

The curve is given by

$$Y_t = A + K\exp(-\exp(-b \cdot \{t - m\}))$$ **Equation 1**

where

Y_t = demand at time *t*

t = time

A = lower asymptote for demand. We assume A = 0 for the rest of this paper

K = upper limit on demand

m = point of maximum growth in y

b = percentage growth in Y at $t = m$

If we know K, b and m then we can simply use the curve. However, more normally we know K, current demand Y_0, and the current growth rate of demand $\left.\frac{dY}{dt}\right|_{t=0}$. To calibrate the curve, we can solve Equation 1 with $A = 0$.

$$b = \frac{\ln(\ln(K) - \ln(Y_0))}{m - t_0}$$ **Equation 2**

Differentiating Equation 1 with respect to *t* gives:

$$\frac{dY}{dt} = Y_t \cdot b \cdot \exp(b \cdot \{m - t\})$$ **Equation 3**

Solving Equations 2 and 3 gives:

$$m = t_0 + Y_0 \cdot \{\ln(K) - \ln(Y_0)\}\frac{\ln(\ln(K) - \ln(Y_0))}{dY/dt}$$ **Equation 4**

Appendix C: Calculating the termination value

To 2026 we discount net benefits at the standard discount rate to reflect social time preference for immediate r than future consumption. HM Treasury sets this at 3.5% per annum. Starting at time $t = 0$, future benefits are discounted using the discount factor δ_t at any given year *t*, and is given by

$$\delta_t = \left(\frac{1}{1+r} \right)^t$$

Where *r* is the discount rate.

Communications technologies rapidly become obsolete and this is reflected by modelling the probability of the net benefits of using LE spectrum occurring. We propose to assume that:

- Up to 2026 the probability of the net benefits generated by the use of LE spectrum is 100%
- The probability then declines by *x*% per annum

The termination value (TV) of the net benefit stream B_t in 2026.

We assume that the net benefit is constant from 2026 onwards, i.e. $B_t = B$ for $t > 20$, i.e. 20 years from 2006. Then:

$$TV = B + \alpha B + \alpha^2 B + \alpha^3 B + \cdots$$

Where $\alpha = \dfrac{1-x}{1+r}$

The sum of this geometric series is

$$TV = \frac{B}{1-\alpha}$$

And substituting for α gives

$$TV = B \cdot \frac{1+r}{r+x}$$

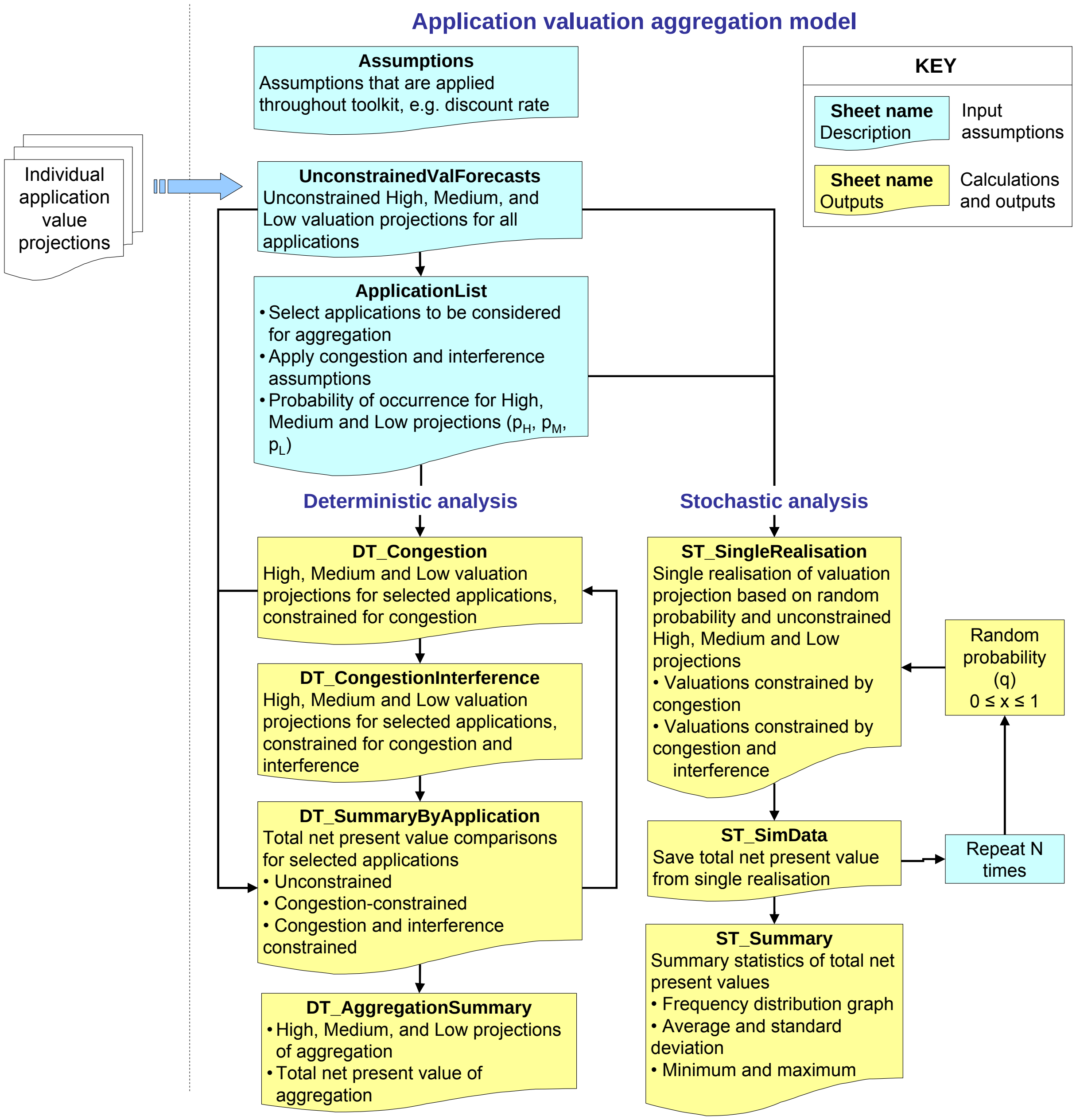
If $r = 3.5\%$ and $x = 10\%$ then $TV = \dfrac{1.0035}{0.135} \cdot B \cong 7.7B$.

Annex D User guide to the aggregation toolkit

D1 Overview

The toolkit developed for this study is designed to help Ofcom calculate the aggregate economic value of a selected set of applications which use the same frequency band. The valuation projections for individual applications, as outlined in Section 2, are used as the primary input to the toolkit. It is then up to the user to select a sub-set of these applications which are to share the same frequency band. Based on user-specified assumptions, this toolkit can then be used to assess the impact of congestion and interference on the aggregate economic value so as to reflect the uncertainty which is inherent in the individual application projections. An overview of the toolkit is illustrated below.

Figure D55 – Overview of application valuation aggregation model



D2 Input assumptions

Input assumptions are shaded blue throughout the toolkit. Major assumptions, which are used throughout, are specified in the "Assumptions" sheet. They are:

- Discount rate – initially set at 3.5 per cent per annum. The annual benefits are discounted at this rate to obtain the total net present value of the benefits.
- Probability of superior technology post 2026 – initially set at 10 per cent per annum. This reflects the rate at which communications technology becomes obsolete and the likelihood that the application we are considering is replaced beyond 2026.
- Termination factor. See Annex C for the formula used to derive the multiplicative factor using the discount rate and the probability of superior technology.

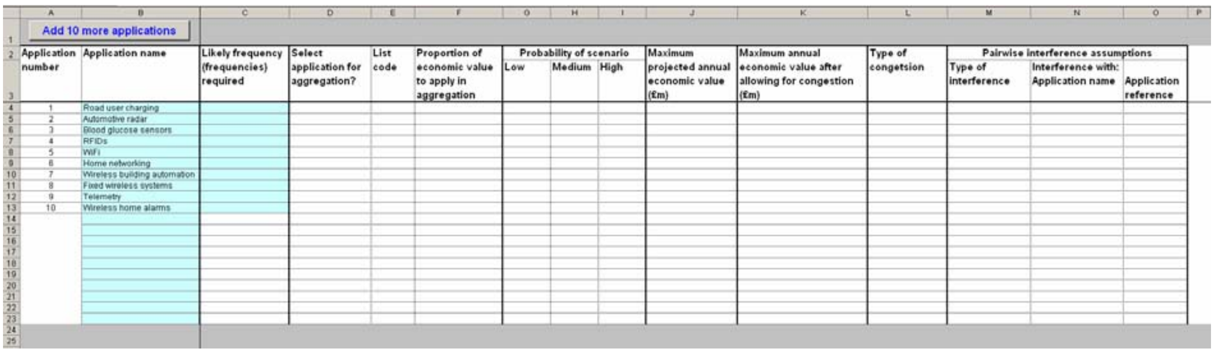
The time dimension of the toolkit are given by:

- Start Year. This is currently assumed to be 2006, and we discount the benefits to this year. In future this can be updated so that the analysis is based on the current year.
- Final Year for evaluating net present values. We have evaluated the net present values of the different applications over a 20 year period. The termination value is calculated using the benefits at the Final Year (i.e. 2026 in our analysis), multiplied by the termination factor and then discounted to the Start year.
- End Year of forecasts. In general we have adopted a 20 year forecast in line with the Final Year for evaluating net present values. However, for Application 3 (active medical implants) the benefits streams start 20 years or more on for Type I diabetics and 40 years or more on for Type II diabetics. As a result we extend the forecasts for this application to 2076.

The user can change these parameters as appropriate.

D3 List of applications

The default number of applications that can be selected for aggregation is set at 20. However, this can be increased as discussed in D4 below.


Add 10 more applications

Application number	Application name	Likely frequency (frequencies) required	Select application for aggregation?	List code	Proportion of economic value to apply in aggregation	Probability of scenario			Maximum projected annual economic value (£m)	Maximum annual economic value after allowing for congestion (£m)	Type of congetsion	Pairwise interference assumptions		
						Low	Medium	High				Type of interference	Interference with: Application name	Application reference
1	Road user charging													
2	Automotive radar													
3	Blood glucose sensors													
4	RFIDs													
5	WiFi													
6	Home networking													
7	Wireless building automation													
8	Fixed wireless systems													
9	Telemetry													
10	Wireless home alarms													

This "Applications List" sheet summarises the characteristics of the applications in terms of:

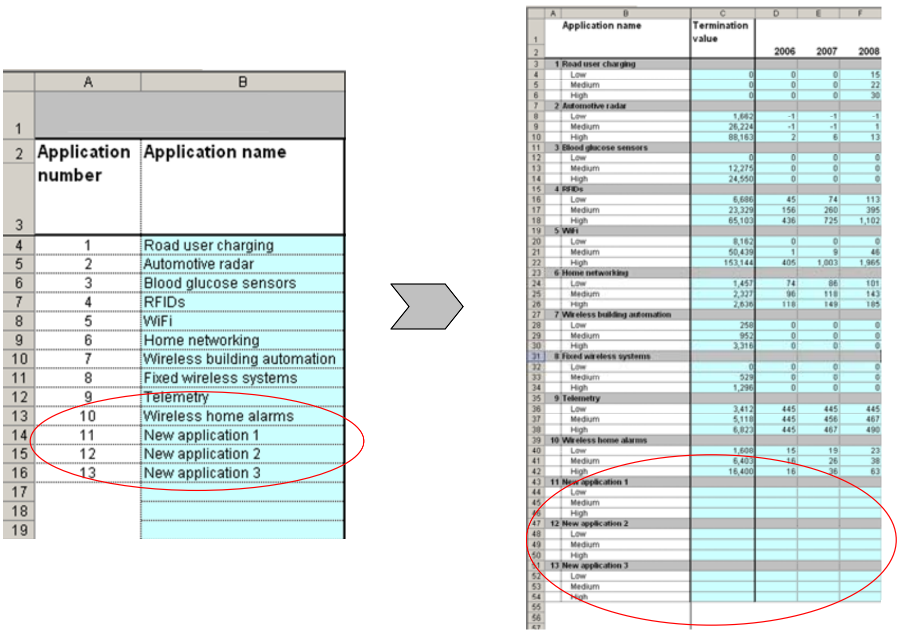
- The likely frequency (frequencies) required. Note that this does not impact the results of the aggregation, but serves as background information as to the most sensible applications to aggregate together.

- Select application for aggregation. The drop down box allows the user to enter either "Yes" or "No". If the former is selected, additional cells are highlighted in blue requesting further input assumptions.
- Proportion of economic value to apply in aggregation. For some applications more than one frequency will be required, and therefore only part of the total value associated with the application should be attributed to the frequency under consideration. Typically this proportion is set at 100 per cent.
- Probability of scenario occurrence. For each of the applications there are three scenarios for the valuation projections – Low, Medium and High. By attributing probabilities to each of these scenarios, we reflect uncertainties in the projections. The probabilities should sum to one
- Maximum annual economic value after allowing for congestion. This is the V_{max} discussed in Section 3.5, and is the maximum value of an application above which congestion limits demand and hence prevents further increases in economic value. For information purposes, the projected unconstrained maximum value is provided in the column on the left hand side.
- Type of congestion. We consider two cases: "No congestion" versus "Some congestion". Note that V_{max} is ignored if "No congestion" is selected regardless of whether or not a value is entered.
- Pairwise interference assumptions. We consider three cases: "No interference", "100% interference" and "Partial interference". These correspond to Curves 1, 2 and 5 of Figure 3.5. If an application interferes, the user is asked to select the application that it interferes with.

Once the input assumptions have been filled in, we consider the following tasks that a user may want to carry out:

D4 Adding new applications

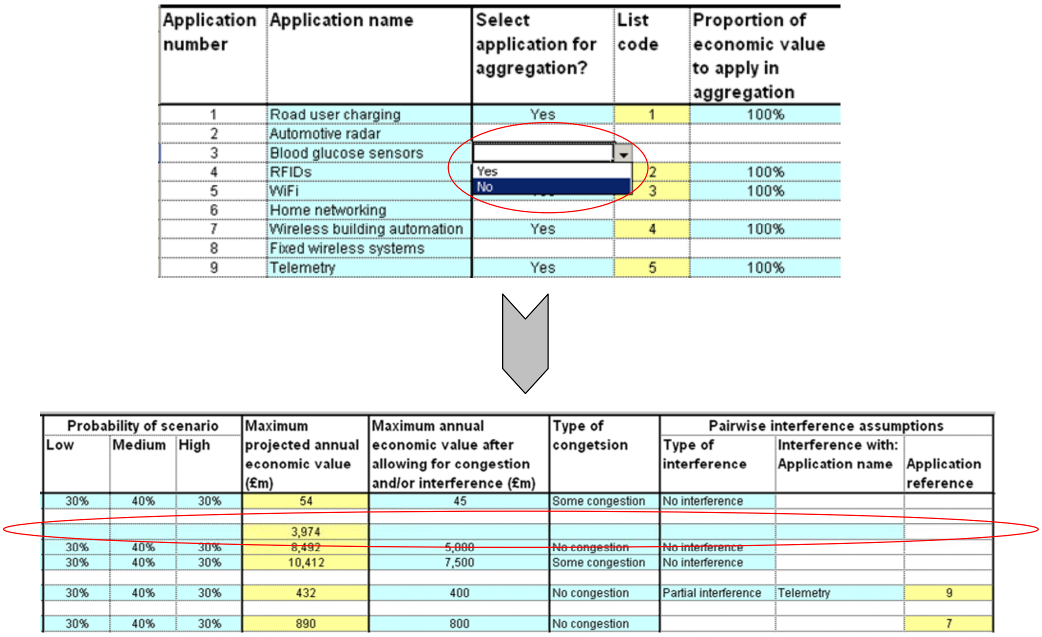
The default number of applications that can be taken into account in the aggregation analysis is set at 20, of which 10 have been used for the applications considered in this study. To add new applications, simply fill in the application name as shown, and then the unconstrained economic values.



Once the 20 applications have been filled up, the user can click on the “Add 10 more applications” button to allow 10 more applications to be considered, up to the limit of the spreadsheet, at 66,000.

D5 Selecting applications for aggregation

Once the input assumptions for the set of applications have been chosen, the user can select up to ten the applications to aggregate, as shown below.

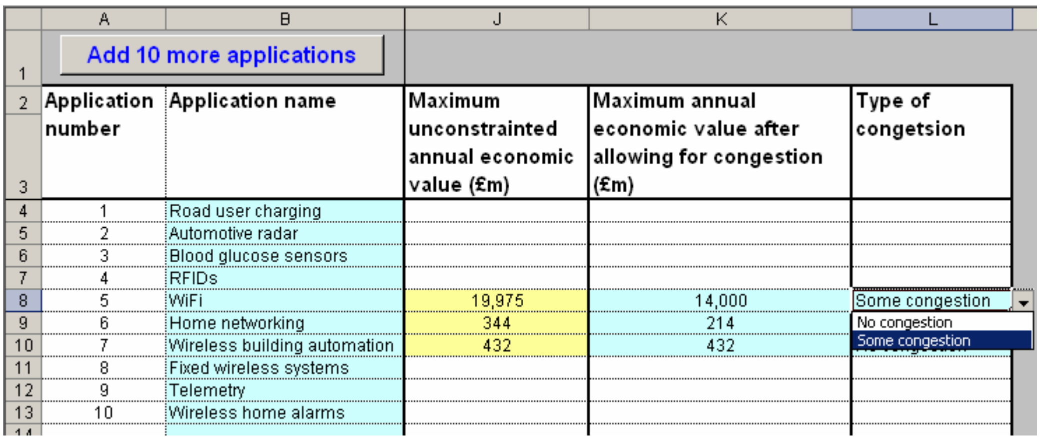


Application number	Application name	Select application for aggregation?	List code	Proportion of economic value to apply in aggregation
1	Road user charging	Yes	1	100%
2	Automotive radar			
3	Blood glucose sensors			
4	RFIDs	Yes	2	100%
5	WiFi	No	3	100%
6	Home networking			
7	Wireless building automation	Yes	4	100%
8	Fixed wireless systems			
9	Telemetry	Yes	5	100%

Probability of scenario			Maximum projected annual economic value (£m)	Maximum annual economic value after allowing for congestion and/or interference (£m)	Type of congetsion	Pairwise interference assumptions		
Low	Medium	High				Type of interference	Interference with: Application name	Application reference
30%	40%	30%	54	45	Some congestion	No interference		
			3,974					
30%	40%	30%	8,492	5,000	No congestion	No interference		
30%	40%	30%	10,412	7,500	Some congestion	No interference		
30%	40%	30%	432	400	No congestion	Partial interference	Telemetry	9
30%	40%	30%	890	800	No congestion			7

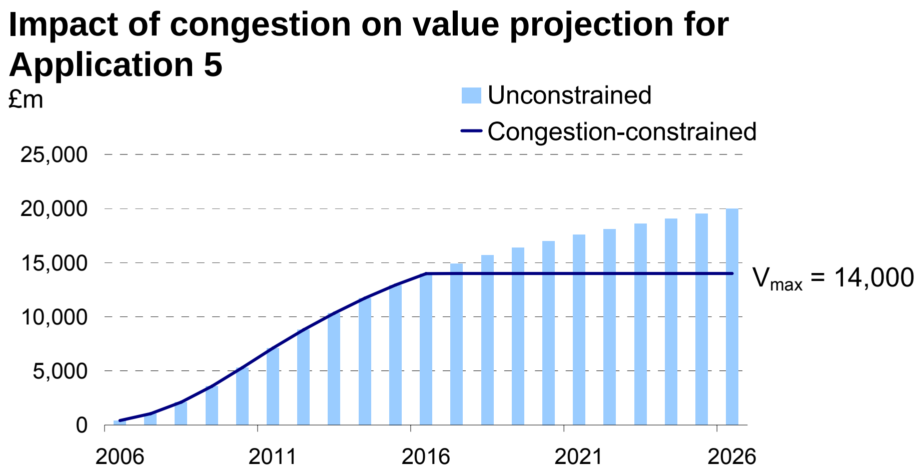
D6 Allowing for congestion

To change the assumptions on congestion, use the drop down box to select one of two options “No congestion” or “Some congestion”.



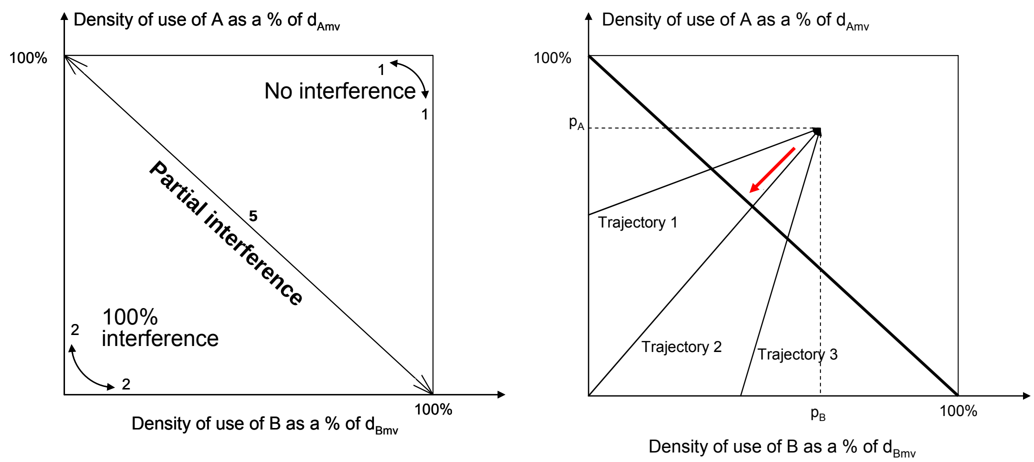
	A	B	J	K	L
2–3	Application number	Application name	Maximum unconstrainted annual economic value (£m)	Maximum annual economic value after allowing for congestion (£m)	Type of congetsion
4	1	Road user charging			
5	2	Automotive radar			
6	3	Blood glucose sensors			
7	4	RFIDs			
8	5	WiFi	19,975	14,000	Some congestion
9	6	Home networking	344	214	No congestion
10	7	Wireless building automation	432	432	Some congestion
11	8	Fixed wireless systems			
12	9	Telemetry			
13	10	Wireless home alarms			

The effect of applying the congestion constraint is illustrated below using the high demand scenario for Application 5, where after 2016 the total economic value does not grow beyond the assumed maximum of £14 billion pa.

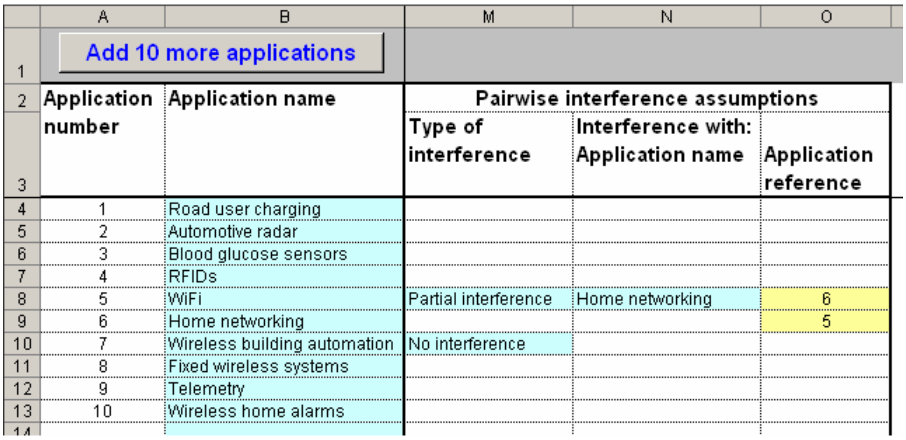


D7 Allowing for interference

As described in Section 3.3, we model three types of interference scenarios in the toolkit as illustrated below. We assume Trajectory 2 in scaling back the value for interference.



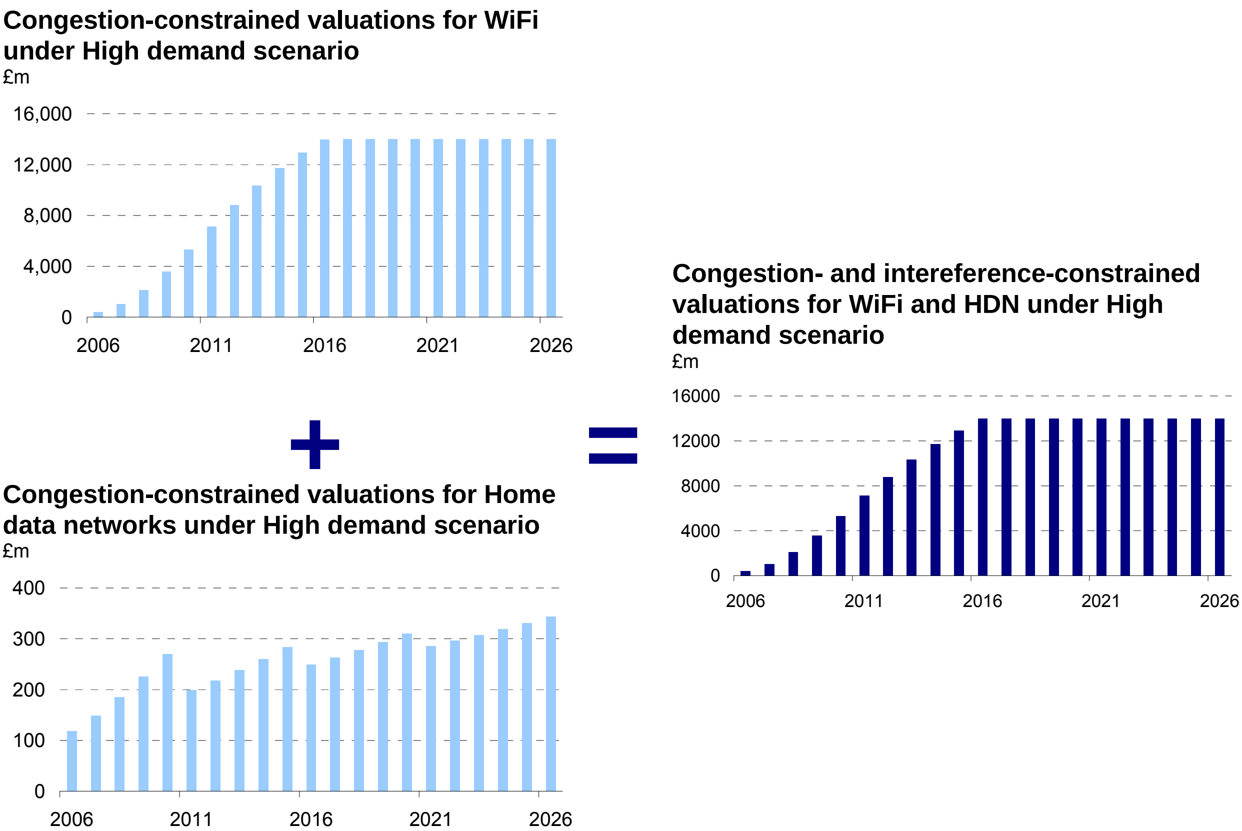
To apply these assumptions, select the appropriate option in the "Pairwise interference assumption" section in the "ApplicationList" sheet.



	A	B	M	N	O
1	Add 10 more applications				
2	Application number	Application name	Pairwise interference assumptions		
3			Type of interference	Interference with: Application name	Application reference
4	1	Road user charging			
5	2	Automotive radar			
6	3	Blood glucose sensors			
7	4	RFIDs			
8	5	WiFi	Partial interference	Home networking	6
9	6	Home networking			5
10	7	Wireless building automation	No interference		
11	8	Fixed wireless systems			
12	9	Telemetry			
13	10	Wireless home alarms			

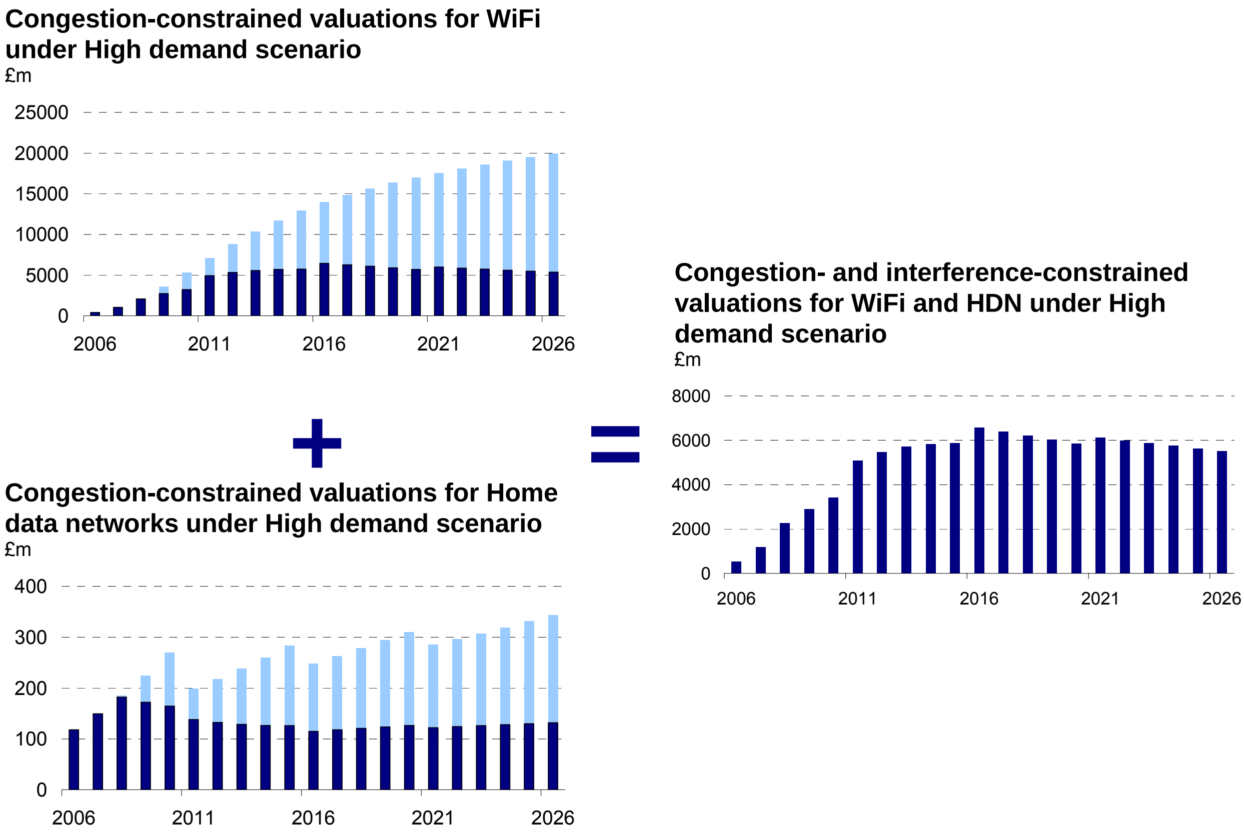
Under the "100% interference" or mutually destructive interference scenario, the application with the higher total net present value is assumed to survive under interference. Using the above example, the total economic benefits from home data networking is significantly smaller than that of Public Access WiFi, and therefore the combined valuation mirrors that of Public Access WiFi.

Impact of applying the 100% interference assumption



On the other hand, with partial interference, both applications are reduced as shown below.

Impact of applying the partial interference assumption

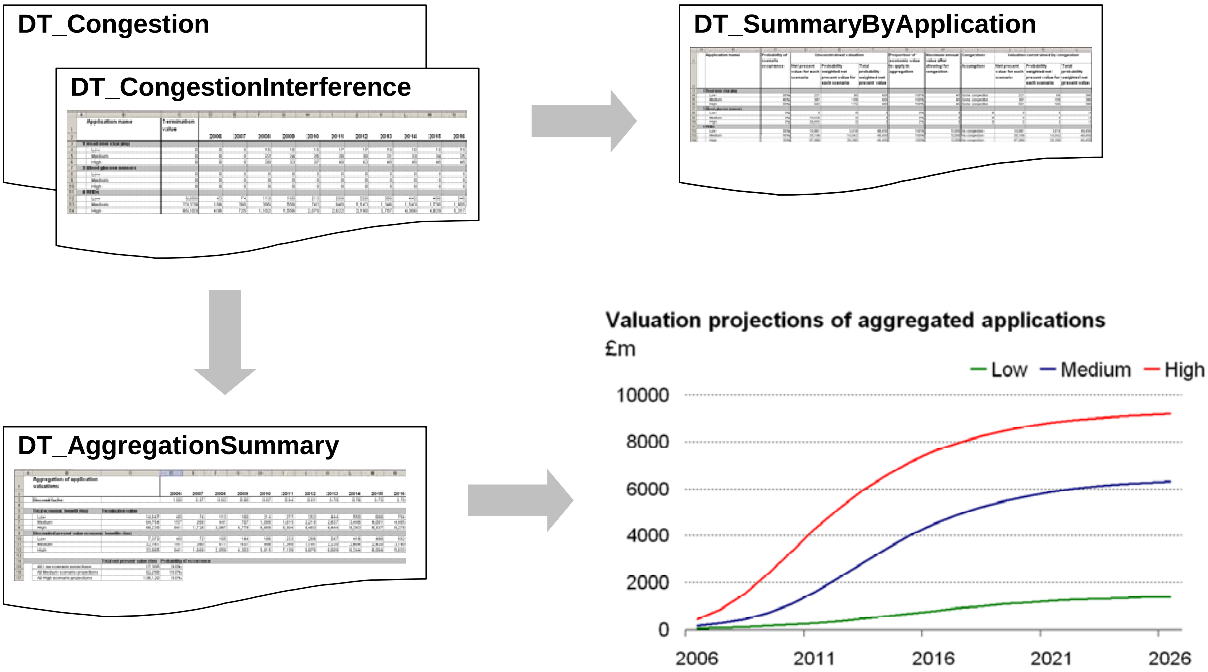


D8 Deterministic aggregation

The toolkit allows two types of aggregation - deterministic and stochastic. The deterministic approach allows the user to obtain an indication of the range of the aggregated values, whereas the stochastic method provides the statistics around the estimates, such as the average and standard deviation.

Under the deterministic aggregation the toolkit:

- Modifies the high, medium and low projections of the applications selected for aggregation to take account of congestion effects as described above. The resulting projections are stored in ***DT_Congestion***
- Constrains the projections further to take account of interference effects, again using the procedures described above, and storing the results in ***DT_CongestionInterference***
- Sums the NPVs of the selected applications, tabulating the unconstrained, congestion constrained, and congestion and interference constrained values in ***DT_SummaryByApplication***
- Estimates the aggregated value of the selection applications when constrained by both congestion and interference in ***DT_AggregationSummary***. This spreadsheet estimates the aggregated value if all the low value projections are realised, if all the medium value projections are realised and if all the high value projections are realised. It also calculates the probability of each of these combinations of projections occurring. Finally it allows the user to calculate the aggregated value of a manually selected combination of high, medium and low projections from the applications selected for aggregation as shown below



5		User defined set of scenarios for aggregation		
6			Select scenario to aggregate	Probability of scenario occurrence
7	5	WiFi	Low	30%
8	6	Home networking	Medium	40%
9	7	Wireless building automation	High	30%
10				

D9 Stochastic aggregation

The stochastic aggregation uses Monte Carlo methods to produce a frequency distribution of aggregated net present values. The toolkit generates a random number **Q** between 0 and 1 for each selected application. It then uses Q to generate a realisation of the projected value of the application. For example, if Q = 27% then the realisation is close to the low projection whereas if Q = 80% the realisation is close to the high projection. We use the equations of Box D1 to produce the realisation.

Box D1 The process for generating a stochastic realisation of a projection

We have three deterministic value projections for each application $V_i(t)$ with associated probabilities of occurrence Pi (i= L, M, H). How can we produce a stochastic realisation of these projections $V_S(t)$ such that:

Expected value $V_S(t) = \Sigma\ p_i V_i(t)$?

The figure below shows our approach. We approximate the cumulative distribution of V(t) with three line segments. We then calculate the end points of the segments x_i as follows:

$x_1 = 1.5{*}V_L - 0.5{*}V_M$

$x_2 = (V_L + V_M)/2$

$x_3 = 1.5{*}V_M - 0.5{*}V_L$

$x_4 = 2{*}V_H - 1.5{*}V_M + 0.5{*}V_L$

We then generate a random number Q between 0 and 1 to calculate V_S as follows:
If Q <= P_L then

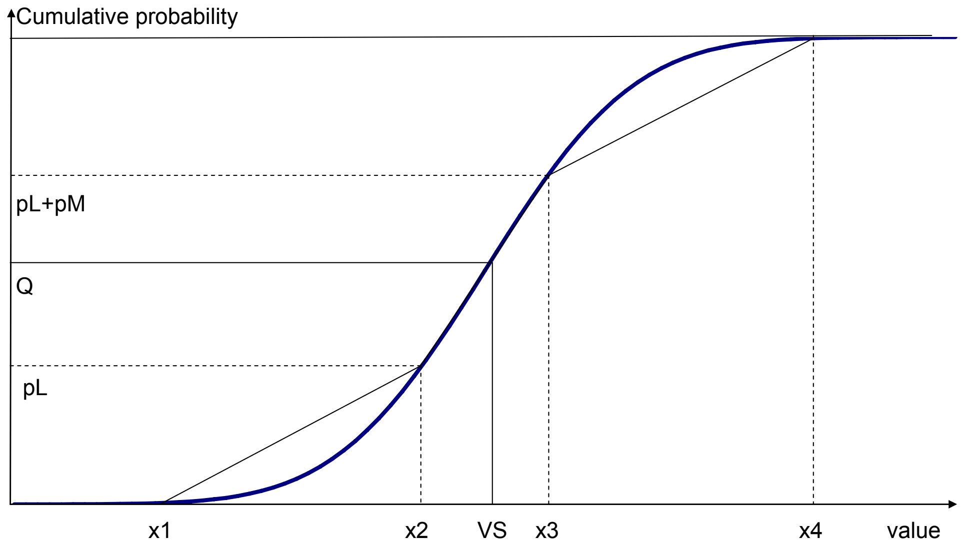
$V_S = \text{Max}[x1 + (x2 - x1){*}(Q/P_L), 0]$

If Q <= $P_L + P_M$ then

$V_S = x2 + (x3 - x2){*}(Q - P_L)/P_M$

Else

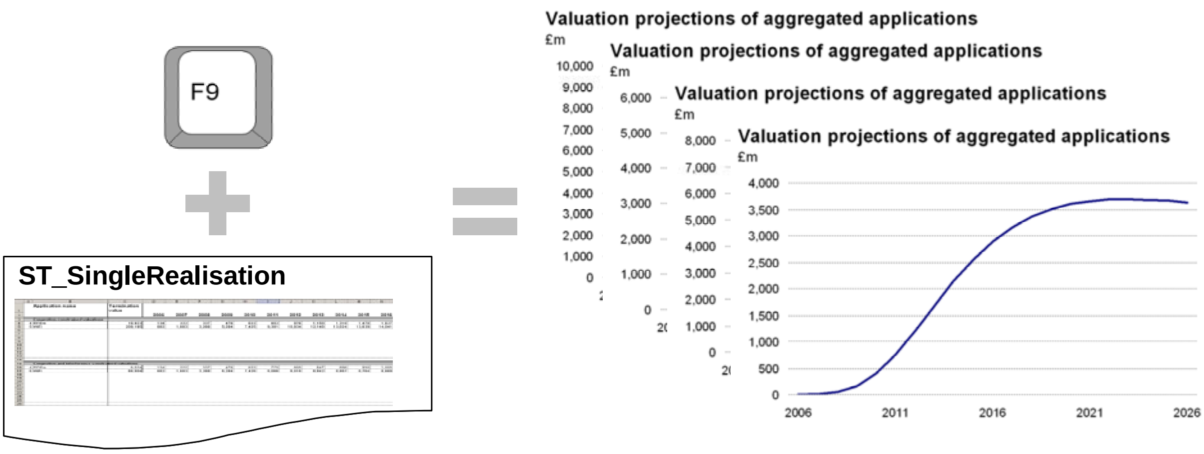
$V_S = x3 + (x4 - x3){*}(Q – [P_M+P_L])/(1 – [P_M+P_L])$



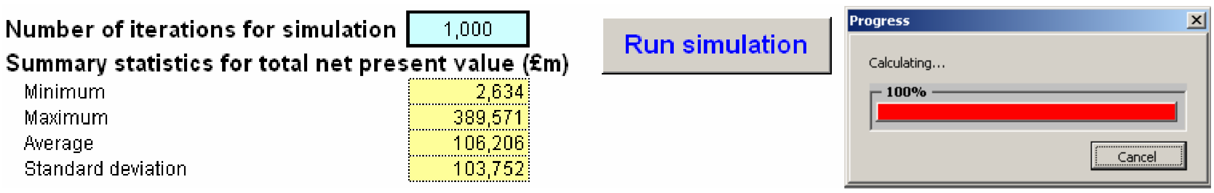
For each realisation we then:

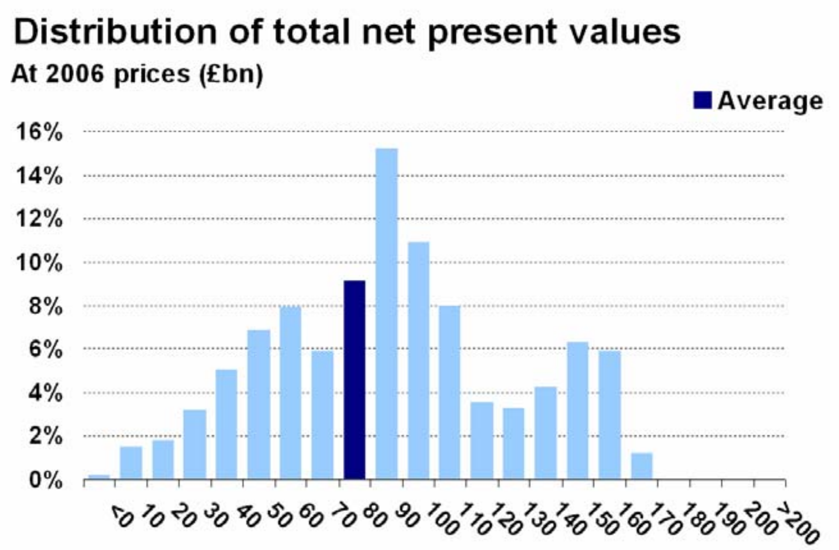
- Apply the congestion and interference constraints to this projection using the procedures of Box 3.2 and store the result in ***ST_SingleRealisation*** for each selected application
- Sum over the constrained projections to derive the aggregate value projection, calculate the NPV of this projection, and store the result in ***ST_SimData***

Each time the user presses the F9 key the toolkit generates a new set of realisations for the selected applications as shown in the diagrams below.



Repeating this process many times then provides us with a distribution of total aggregate net present values, as shown in the frequency distribution graph below. The “Cancel” button on the Progress bar can be pressed at any time to halt the calculations.

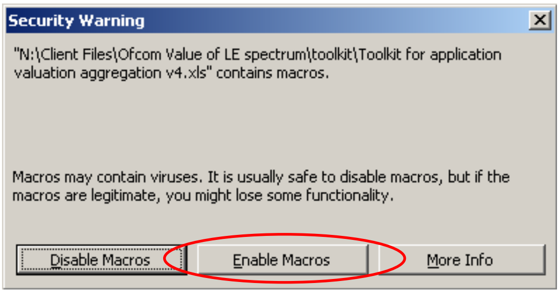




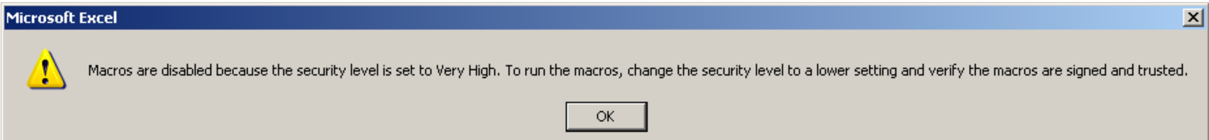
D10 Macro security level

Please note that the toolkit uses Microsoft Excel macros, and the macro security level must be set at “Medium” to enable the calculations to be carried out.

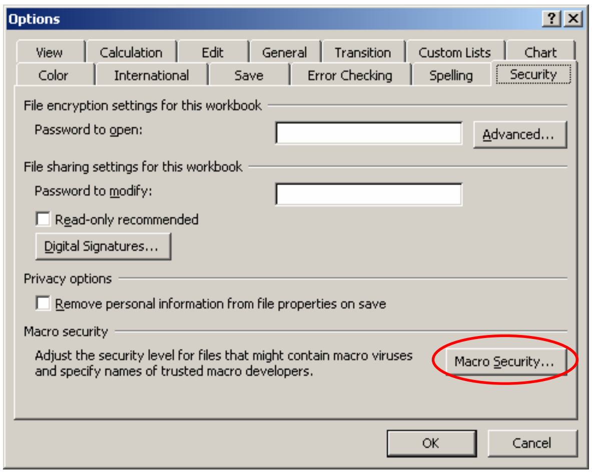
If the following message appears upon opening of the toolkit, select “Enable Macros”, and this should take the user to the Introduction sheet.

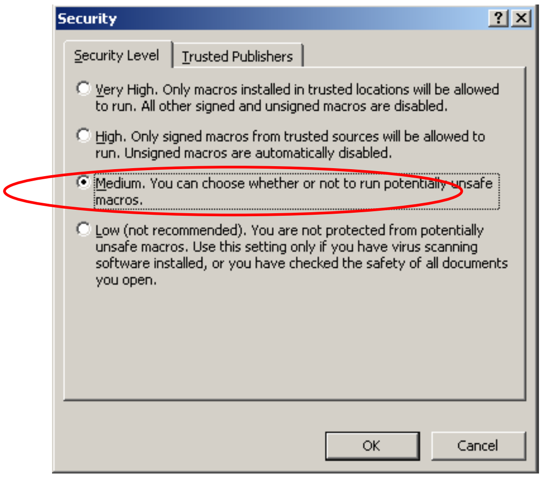


If, on the other hand, the following message appears, click “OK” and on the toolbar, select “Tools” and then “Options”.



Select the “Security” tab to change the security settings as shown.





Once this is done, close the toolkit and re-open. This should direct the user straight to the Introduction sheet.

Note that if the macros are disabled, the congestion and interference valuations would not be calculated, and therefore the results would not correspond to the set of assumptions entered.

Appendix E Mapping of applications with parallel studies

Ofcom commissioned two parallel studies on different aspects of LE spectrum at the same time as it commissioned the study reported on here. There are three studies which use the concept of applications. These are:

- The ***Eco-LE*** study on the economic value of LE spectrum ie the current study
- The ***AS-LE*** study which considers the case for application specific designations of LE spectrum
- The ***HF-LE*** study which looks at the case for designating all spectrum above a certain frequency as LE.

The three study teams have coordinated closely to maximise common use of the same definitions of applications. But the three studies have very different objectives and it has not always been appropriate to use the same application set or definitions. So in this appendix we highlight the differences where they exist to provide a mapping between the terms used in the three studies.

Figure E1 summarises the findings. We have grouped the applications as follows:

- Applications 1 to 5[155] are labels which all three studies use. The table indicates where there are differences in the use of these five labels
- Applications 6 to 10 involve labels which the Eco-LE and AS-LE studies use but not the HF-LE study. This reflects the fact that there are applications where high frequencies (>30GHz) are not used
- Application 11 to 13 are labels which the AS-LE and HF-LE studies both use but which are not used in the Eco-LE study
- Applications 14 onwards are labels which are used by only one of the three studies and where there are no mapping problems.

In addition to the application labels used in the table, the HF-LE and AS-LE studies also used the label *personal area networks* or *PANs*. In the AS-LE study this involves use of ultra wide band technology to connect office and home devices at ranges of a few meters or less. In the HF-LE study the term is used interchangeably with indoor Gigabit WLANs (Application 14 in the table).

It is useful to note how these differences have arisen because of the different objectives of the three studies:

- the Eco-LE study selected 10 very different applications for which to make economic value projections. It did not attempt to be comprehensive and it only made value projections for those impacts where it was credible to do so
- the AS-LE study considers all of the Eco-LE applications plus some additional, major, applications not covered in the Eco-LE study. In some cases it uses a wider definition than Eco- LE study and, in carrying out detailed interference modelling, assumes that applications will share frequencies. So Scenario 1 of this modelling has Applications 2, 5 and 9 sharing spectrum at 5.8 GHz while Scenario 2 has applications 8, 13, and 19 sharing bandwidth at 0.4 GHz for interference modelling purposes

[155] Note that this numbering is different from that used in the Eco-LE study when referencing applications

- the HF-LE study considers only applications over 30 GHz. So it does not consider many of the applications covered the Eco-LE and AS-LE studies. In some cases (e.g. Applications 2, 4, 19 and 20) the HF-LE study considers high frequency solutions for applications which are already served at low frequencies to some extent.

Ref	Status	General label	Eco-LE	AS LE	HF LE (>30GHz)
1	All 3	Home entertainment/Home network	Wireless home networking at 2.4 GHz. Includes data networking but not home entertainment	Home entertainment and home data networking at 5.8 GHz	In door Gbit WLANs at 60 GHz
2	All 3	Vehicle anti-collision radar	Use of automotive short range radar to reduce traffic accidents. 24 GHz and 79 GHz	As Eco-LE	Intelligent Transport Systems. Short range radar at 79 GHz and longer range radar at 76-77 GHz. 24GHz not covered given terms of reference
3	All 3	Broadband fixed wireless access	Public access WiFi broadband services - fixed and nomadic at 2.4 and 5 GHz	Fixed broadband using WiMAX technologies at 5.8 GHz	Public access fixed broadband at 40GHz
4	All 3	P2P fixed wireless systems	Fixed wireless systems at 71-76 GHz and 81-86 GHz	As Eco-LE	As Eco-LE
5	All 3	Security and detection devices	Wireless home alarms at 868 MHz, with movement detection at 10 GHz and 24 GHz	As Eco-LE	Short range surveillance radar at around 100 GHz. Starts with applications in the business sector but may eventually be used in the consumer sector
6	Eco+AS	Telemetry	Wireless telemetry in the utilities. at 0.3-30 MHz, 402-405 MHz, 433.05-434.79 MHz, 458.5-459.5 MHz, and 2.4 GHz	Wireless telemetry in all industries	Not covered
7	Eco+AS	Medical	Blood glucose sensors based on implants at 401-406 MHz	As Eco-LE	Not covered
8	Eco+AS	RFID	Use of RFID in the retail sector. 120-148.5 kHz, 13.56 MHz, 865-868 MHz, 2.4 GHz. Includes in-store applications as well as inventory tracking	RFIDs used for inventory tracking at 450 MHz. Covers retail and other industries	Not covered
9	Eco+AS	Road tolling	Road user charging using DSRC technology. 5.8 GHz	As Eco-LE	Not covered
10	Eco+AS	Wireless building automation	Wireless building automation at 2.4 GHz	As Eco-LE	Not covered
11	AS+HF	Short range high capacity repeaters	Not covered	As HF-LE	Repeaters at 64-66 GHz to provide backhaul for a range of wireless applications
12	AS+HF	HAPS broadband	Not covered	As HF-LE	Yes
13	AS+HF	Mobile broadband for public safety	Not covered	Mobile broadband at 450 MHz using CDMA with limited bandwidth	Microwave mobile broadband at >30GHz
14	AS+HF	Gbit WLAN	Not covered	Not covered	Outdoor Gbit WLAN at 40-100 GHz
15	HF only	Direct broadcasting satellite	Not covered	Not covered	At 40.5-42.5 GHz and 45.5-47.0 GHz
16	HF only	Aircraft to satellite communications link	Not covered	Not covered	Yes
17	HF only	SuperBUS	Not covered	Not covered	Yes to connect home and office devices at >100GHz
18	HF only	Wireless HDTV cameras	Not covered	Not covered	Yes - at and above 60 GHz for connecting TV studio equipment
19	AS only	Roadside to vehicle communication	Not covered	Roadside to vehicle at 450 MHz using TDAB	Part of intelligent transport systems at 63 -64 GHz
20	AS only	Vehicle to vehicle communication	Not covered	Vehicle to vehicle communication of driver information. No technical specification considered given that there is no detailed modelling	Part of intelligent transport systems at 63 -64 GHz