Smart Home Systems and the Code for Sustainable Homes

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The objective of this report is to identify the role smart home solutions could play in supporting delivery of the performance levels of the Code for Sustainable Homes. The report provides an evidence base, including case studies, demonstrating how smart home solutions can be used to enhance the environmental, economic and social sustainability of homes.

The first section summarises the requirements of the Code for Sustainable Homes, and identifies the beneficial impact of smart home systems. The areas of the Code where smart home solutions can contribute to enhancing sustainability are described. A series of case studies provide practical demonstrations of smart home installations and their benefits.

The report provides the start of an evidence base linking integrated smart home (and building) technologies to environmental and sustainability benefits (1).

An additional purpose of the report is to facilitate a dialogue about how the Code for Sustainable Homes might be revised to include performance requirements based on smart home technologies.
The Code for Sustainable Homes, published in April 2007, provides an assessment method for environmental performance for new homes in England. Environmental performance is divided into nine categories, shown in Table 1 below. The Code’s performance levels cover a scale of 1 to 6, 6 being the maximum.

The Code is concerned with maximising the effective use of scarce resources in new build homes. Smart home technologies have a potentially important role in monitoring & managing resource use in the home setting.

Table 1 outlines the individual elements of the Code, how much they contribute to the overall score, mandatory elements and, identifies where smart home systems could support or extend the Code performance Levels. Case studies, located in Appendix I, are referenced in the final column of the table. The key areas where smart home systems might add value are outlined the sections that follow.

### Table 1: Elements of the Code

<table>
<thead>
<tr>
<th>Category</th>
<th>Weighting</th>
<th>Mandatory</th>
<th>Role for IB Systems</th>
<th>Example Integrated Technologies &amp; Systems (Case Studies)</th>
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<tbody>
<tr>
<td><strong>1 Energy &amp; Carbon Dioxide Emissions</strong></td>
<td>36.4%</td>
<td>✓</td>
<td>✓</td>
<td>Community-wide energy management systems; smart meters &amp; energy displays; programmable thermostats; radiator valve actuators; boiler maintenance tags; (1, 2, 3, 4, 5, 6, 7, 9, 10)</td>
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<tr>
<td>Dwelling Emission Rate</td>
<td>18.9%</td>
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<td>✓</td>
<td></td>
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<tr>
<td>Building Fabric</td>
<td>2.52%</td>
<td>✓</td>
<td>✓</td>
<td>Fabric mounted heat flow sensors to monitor insulation performance</td>
</tr>
<tr>
<td>Internal Lighting</td>
<td>2.52%</td>
<td>✓</td>
<td>✓</td>
<td>Occupancy sensors, timer switches, auto-off switches, daylight sensors, central-off, panic buttons (2, 3, 4, 5, 6, 11)</td>
</tr>
<tr>
<td>Drying Space</td>
<td>1.26%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Energy Labelled White Goods</td>
<td>2.52%</td>
<td>✓</td>
<td>✓</td>
<td>Chip enabled white goods</td>
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<tr>
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<td>✓</td>
<td>PIR sensors, daylight sensors (8)</td>
</tr>
<tr>
<td>Low or Zero Carbon Technologies</td>
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<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Cycle Storage</td>
<td>1.26%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Home Office</td>
<td>2.52%</td>
<td>✓</td>
<td>✓</td>
<td>House-wide communications network and data outlets (6, 7)</td>
</tr>
<tr>
<td><strong>2 Water</strong></td>
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<td>Water management systems, grey water recycling (6, 7)</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>External Water Use</td>
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<td>✓</td>
<td>✓</td>
<td>Rain water harvesting for, eg toilets</td>
</tr>
<tr>
<td><strong>3 Materials</strong></td>
<td>7.20%</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Environmental Impact of Materials</td>
<td>4.50%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Responsible Sourcing of Materials – Basic Building Elements</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsible Sourcing of Materials – Finishing Elements</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>4 Surface Water Run-off</strong></td>
<td>2.20%</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Reduction of Surface Water Run-off from the Site</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood Risk</td>
<td>1.10%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>5 Waste</strong></td>
<td>6.40%</td>
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<td></td>
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<tr>
<td>Household Waste Storage and Recycling Facilities</td>
<td>3.64%</td>
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<td>Construction Site Waste Management</td>
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<td>✓</td>
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<tr>
<td>Composting</td>
<td>0.91%</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>6 Pollution</strong></td>
<td>2.80%</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Global Warming Potential of Insulants</td>
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<td>✓</td>
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<tr>
<td>NOx Emissions</td>
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<td></td>
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<tr>
<td><strong>7 Health &amp; Well-being</strong></td>
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<td>Daylighting</td>
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<td>Daylight linked lighting and blind controls (2, 5)</td>
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<td>Private Space</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Lifetime Homes</td>
<td>4.68%</td>
<td>✓</td>
<td>✓</td>
<td>Assistive living: Telecare and telehealth solutions (11)</td>
</tr>
<tr>
<td><strong>8 Management</strong></td>
<td>10.0%</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Home User Guide</td>
<td>3.33%</td>
<td>✓</td>
<td>✓</td>
<td>Online house user guide</td>
</tr>
<tr>
<td>Considerate Constructors Scheme</td>
<td>2.22%</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>Construction Site Impacts</td>
<td>2.22%</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>Security</td>
<td>2.22%</td>
<td>✓</td>
<td>✓</td>
<td>Video linked door entry systems (6, 11)</td>
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<tr>
<td><strong>9 Ecology</strong></td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Ecological Value of the Site</td>
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<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Ecological Enhancement</td>
<td>1.33%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Protection of Ecological Features</td>
<td>1.33%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Change in Ecological Value of Site</td>
<td>5.32%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Building Footprint</td>
<td>2.66%</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
2.1 Dwelling Emission Rate

This refers to a dwelling’s estimated annual carbon emissions per unit of floor area, for heating, hot water and lighting, based upon SAP 2005 (Standard Assessment Procedure). This is the highest valued performance element in the Code.

A range of smart building services can support Dwelling Emission Rate performance criteria. These monitor and inform how SAP-predicted energy efficiency is achieved in practice, including:

- Monitoring and informing use of energy within the building, where energy use is sub-metered in categories including:
  - Hot water heating
  - Space heating
  - Lighting
  - Appliances, particularly white goods.

- Monitoring the temperatures of indoor air and domestic hot water to identify energy waste overheating air or water.

- Monitoring humidity (or air quality indicators, such as CO\textsubscript{2}) to determine if ventilation is inadequate or whether there is more ventilation than necessary.

2.2 Building Fabric

This element of the Code is concerned with future proofing the energy efficiency of dwellings over their whole life by limiting heat losses across the building envelope. Again, this is based on SAP 2005.

Building Fabric can be monitored by installing heat flow sensors linked to an intelligent building system, using sensors to monitor the flow of heat through the roof, walls and floor.

2.3 Internal Lighting

The Code encourages the use of energy efficient internal lighting to reduce CO\textsubscript{2} emissions from the dwelling. This element refers to the proportion of fixed internal fittings that are and energy efficient.

While SAP calculations deal with the planned lighting, it would be possible for a smart home system to monitor energy use for lighting. Devices for helping reduce lighting energy use could include, for example:

- Occupancy sensors
- Timer switches
- Auto-off switches, requiring the home occupier to switch lighting back on.

2.4 Drying Space

This provides for a low-energy means of drying clothes, either indoors or outdoors.

2.5 Energy Labelled White Goods

Performance level points are awarded for the presence of energy efficient white goods.

White goods – washing machines, dishwashers and fridges & freezers – fitted with electronic energy monitoring and management components can ensure more effective energy use.
2.11 Daylighting
This element aims to improve the quality of life in homes through good daylighting and to reduce the need for energy to light the home.

Using daylight sensors, internal lighting can be made responsive to outdoor light levels, ensuring that electric lighting use is reduced to a minimum, while sufficient to satisfy the need of home occupiers.

2.12 Lifetime Homes
The Code encourages the construction of new homes that are accessible to everybody, and where the layout can easily be adapted to meet the future needs of occupants, as their lifestyle needs change with age.

Smart home systems can support special needs, particularly services that support the elderly. Examples of this may be safety-related, including for example:

- Hypothermia alerts
- Flood avoidance and flood detection (using water sensors below sinks and baths)
- Gas detection
- Monitoring humidity to ensure that ventilation is adequate to avoid mould
- Panic buttons
- Telehealth services (for specific medical conditions)

2.13 Home User Guide
Recognise and encourage the provision of guidance to enable home owners & occupiers to understand and operate their smart home services correctly. Access should include appropriate access for occasional users, such as tradesmen.

2.14 Secured by Design
To encourage the design of developments where people feel safe and secure, where crime and disorder, or the fear of crime, does not undermine quality of life or community cohesion.

Smart home systems can increase security by using door-open sensors and occupancy sensors, giving information about intruders. A smart building system can also generate automatic text messages alerting others of danger so that they can take appropriate intervening action. These safety systems can be integrated with smoke sensors and other hazard sensors, set to trigger in the event of fire or other hazardous event. Making people feel safer in their own homes is important, particularly for the elderly.
03 What is a Smart Home?

There are many different definitions of smart homes and buildings. For the purposes of this report smart homes are defined as:

Dwellings that use integrated communication systems to monitor and manage the performance of the home, and to support the lifestyle choices of the occupants.

All smart home systems are comprised of four primary components:

- **Infrastructure**: A communications medium for the transmission of digital information. Current media include copper cable, fibre optic, wireless and powerline, which uses existing electrical power networks.

- **Sensors**: Used to monitor conditions within the home, for example temperature sensors and humidity sensors.

- **Actuators**: Actuators are devices that enact instructions from applications. Examples include actuators to open windows, close radiator valves etc.

- **Applications**: Applications enable people to control the smart systems in their homes. They take the form of algorithms coded into programmes. They enable building users to set parameters such as maximum and minimum temperatures, which the sensors and actuators will monitor and respond to achieve the user set performance.

To deliver the highest levels of user benefit and performance all four elements are bound together in an integrated communications network. This allows traditionally disparate systems to communicate with each other.

It also allows different themes to interact, eg support for the elderly using assistive living technologies linked with temperature sensors to help avoid the onset of hypothermia in winter. Some of these scenarios would be difficult or impossible without the use of integrated digital communications.

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**Figure 1: Integrated Digital Communications in the Built Environment**
04 Smart Home Systems and the Code

The current performance criteria of the Code do not include the use of smart home technologies, which have the potential to deliver significant benefits in support of achieving the different performance levels of the Code. Smart home systems enable:

- Improved environmental performance by enabling buildings and systems to monitor and operate at their optimum levels
- Automatic control of building services to meet the requirements of the end-user or manager by user set control parameters
- Fault reporting, billing and display of energy and carbon usage.

Figure 2 shows how smart home systems can be used to deliver sustainable homes. The diagram links smart home systems to basic end user needs, including:

- Thermal comfort
- Water
- Communications & Entertainment
- Safety & Security
- Lighting
- Health & well-being.

An integrated communications network enables the different smart home systems to communicate with each other, to share information so supporting delivery of improved housing performance.

At the current state of the smart homes market, it is unusual to find all of these systems configured and installed using an integrated communications network, although this is technically achievable.

Commercial barriers often prevent the effective integration of smart home systems. This issue will need to be addressed if there is to be significant uptake of the technically based smart home solutions.

Figure 2: Smart home systems
4.1 Thermal Comfort

Smart home systems can be used to regulate the temperature in homes within set parameters. Case Studies 1 & 2 demonstrate where these systems have been used to deliver significant energy reductions and increases in end-user comfort.

While SAP includes metrics for insulation, or U-values, true U-values are often different because of workmanship and ageing of insulation systems. Monitoring heat flow through the building fabric can indicate whether it would be worthwhile upgrading insulation. It can also help in ensuring that replacement heating systems are optimally sized.

Smart home systems such as automated blinds have the potential to add further value in terms of regulating solar gain and heat-loss as required.

SAP and the Code and concern themselves mainly with minimising heating loads and make little reference to the growing issue of summer overheating. The risk of overheating is significantly increased with highly insulated buildings, unless they are well designed and managed.

The availability of low-cost, easily-installed air-conditioning systems from DIY outlets is leading to an increased number of household installations. This trend has significant implications for energy consumption and the carbon footprint of homes.

Case studies 3, 4, 5, 6 & 7 describe different approaches to achieving increased thermal comfort, while reducing carbon emissions. These case studies, all from the UK, also represent different applications, including:

Case Study 3 – A new build house constructed as a research facility to test the validity of sustainable design concepts and integrated smart home technologies.

Case Study 4 – The installation of smart home technologies in a major refurbishment project.

Case Study 5 – A major, multifunction installation in a large domestic dwelling, demonstrating the power and flexibility of integrated control systems applied to the domestic sector.

Case Studies 6 & 7 – The application of smart home technologies to the social housing sector, demonstrating the validity of the technologies to the cost sensitive, volume housing sector.

4.2 Water

Credits are awarded in the Code based on the predicted average household water usage. Calculations are based on sanitary fittings and grey-water and rainwater systems.

Water management systems can be used to deliver significant water savings, ensuring that water is delivered at the right temperature, in the right quantity for the required task. For example, intelligent water controls can be used to run a bath and will shut off when the bath is full, or to come on for a specified amount of time for example for showers or tooth brushing. These monitoring systems can result in significant reductions in water use.

Water monitoring for leak detection can enable problems to be identified and addressed quickly, saving water and preventing long-term damage to fixtures, fittings, and the building fabric.

Systems to monitor the patterns water use can be used in a social care context. Significant breaks in the pattern of use can alert carers to a potential problem. This can include unusual patterns of use, eg use at unusual hours, or a dramatic reduction in use.

Consultations on updating Part B of the building regulations have recently taken place, exploring the provision of sprinkler systems in domestic premises in order to prevent fire damage. This would need to be incorporated into the design of any future build.

Rainwater butts combined with metered irrigation systems can be used to maintain plants and biodiversity whilst minimising water usage. This type of system was used in the Integer Millennium House at BRE.

4.3 Communications & Entertainment

Homes must be able to respond to the changing demands placed upon them by modern living. People expect to use the latest consumer electronics in their homes, to have house-wide access to broadband Internet, and to have access to the latest digital and satellite media.

Installing an integrated communications network provides connectivity, and - where suitable systems are installed - control throughout the home. The communications network can be used to carry information for a diverse range of applications including home entertainment – mainly video-on-demand and audio. The same network can also carry information for safety & security systems, social alarms and home automation systems.

As a rule of thumb, installing two double internet enabled data sockets per room – with the double data sockets located at approximately opposite locations in each space - allows sufficient flexibility for setting-up a home office. It is also effective to locate the double data sockets adjacent to double power sockets.

Provided the communications medium – cable or wireless – has sufficient bandwidth (information carrying capacity), the network also allows for ease of upgrading or installing new technologies as requirements change, or when cutting-edge technologies become more affordable or reliable.
Smart home systems using an integrated communications network may avoid the need to install expensive standalone systems. Using the network to link the door-entry systems with the telephone and television system means that occupants can use their own television and telephone to grant access.

Given the development specific nature of security, the local police Architectural Liaison Officer (ALO) is interpreter of Secured by Design criteria, which may be subject to variation dependent on the individual. For example, some ALOs will specify video door entry and CCTV while others not. Security needs will also require the use of external lighting systems and car parking systems, where these are appropriate.

Case Studies 3, 4, 6 & 11 demonstrate different applications of integrated smart home technologies to home safety and security.

4.5 Lighting

The current Code makes no provision for the use of integrated lighting control systems. Credits are based on the percentage of dedicated energy-efficient light fittings. However, integrated lighting controls have the potential to optimise the performance of energy-efficient and standard lighting installations.

Features such as dimming, daylight sensors, timers and occupancy sensors can be used to significantly improve the energy efficiency performance of the lighting system – see Case Study 2 – while features such as mood light settings provide end-users with increased satisfaction.

Simple intelligent features such as all-off switches enable occupants to switch off all lights as they leave the home, while ensuring that no appliances have been left on accidentally. Courtesy lights, where the light comes on as the door is opened, while contributing minimally to carbon emissions, provide a low-cost and valued feature for occupants.

Although the two systems are separated in the Code, the internal lighting system can interact with the external lighting system. For the external lighting system, the Code provides for a low level of intelligence in the form of movement and daylight sensors. These sensors can be linked to the higher-level lighting management system to optimise performance.

Communal areas, including lobbies, shared landscaping, parking areas and street lighting are outside the scope of the Code. They are however accounted for in Secured by Design. Integrated lighting systems can be used to significantly reduce energy consumption in these areas.

Case Study 8 demonstrates the benefits of using this approach.

Dwellings designed to make full use of daylighting reduce the need for electrical lighting. Linking lighting systems to daylight availability and the use of blinds and curtain control can ensure maximum use of daylighting control while controlling solar gain, so limiting overheating and glare from the sun.

Facade management systems such as automated brise-soleil, louvers, blinds, curtains and shutters all play a role in facilitating the use of daylight. These facilities go beyond the requirements of the Code, which specifies only levels of daylighting in specific areas.

Work started on site in Oak Grove in spring 2008.

The availability of a home user guide as detailed in the Code provides an opportunity for the introduction of interactive home user manuals. Paper based manuals tend to go missing or quickly become out of date. Intelligent management of online home user guides can overcome this problem, by including updateable and dynamic content such as details of scheduled maintenance through to public transport, and other local service information.

For rented properties, this service can include fault reporting, bookings and tracking. This can provide a basis for communicating other sustainable lifestyle suggestions, such as Swan Housing Group’s ‘Code for Sustainable Living’.

4.4 Safety & Security

The Code does not make specific provision for life safety systems; however, Part B of the Building Regulations states that all new dwellings should be provided with a fire detection and alarm system of at least a Grade D standard. This means that they should be mains operated with a standby power supply. A single independent circuit or a single, regularly used lighting circuit can be used as a power source.

‘Secured by Design’ is rewarded by the Code, but is not mandatory. For Registered Social Landlords it is mandatory. Secured by Design does not require the use of smart home systems, however smart access control systems and CCTV surveillance can significantly enhance the security performance of dwellings.

Where a common entrance serves four or more dwellings, the doors are required to incorporate an access control system, with an electronic lock release and entry phone linked to the flats. Audio Visual verification i.e video door entry is required where ten or more households share a common entrance.
The Barratt Green House at BRE’s Innovation Park features automatic window shutters, which are controlled through a central Building Management System. The system includes manual override, allowing occupants to manually set the blinds and shutters.

Case Studies 3, 4, 5 & 6 all describe UK based lighting applications of integrated smart home technologies.

### 4.6 Health & Wellbeing

The Code makes provision for daylighting, sound insulation, private space and lifetime homes to be incorporated into homes.

Although not specifically a lifetime homes requirement, pre-cabling of homes, enabling telecare and telehealth offers flexibility in adapting the house as the occupants’ life style changes as they get older.

Movement sensors, water and electricity monitoring alarms and warden call systems can send data to local carers or remote alarm monitoring centres, alerting them that there is a problem. These systems enable people to continue living independently, in their own homes for longer, decreasing the cost of adaptations or the need for dedicated housing units. The same systems can also serve to monitor activity, and to raise alarms with carers in the event of some type of critical situation, eg a fall.

Health & wellbeing applications of integrated smart home solutions are outlined in Case Studies 3, 5 & 11.

### 4.7 Smart Metering

The role of occupants and the implications of their behaviour on overall carbon emissions are not fully explored by the Code for Sustainable Homes. Smart meter technology is, potentially, a key component to improving the efficient use of energy in the home setting.

A primary benefit of smart meters is that they provide precise, real time information on energy use and energy costs. Access to this information is intended to facilitate changes in behaviour around energy use.

The impact of smart meters is enhanced if features such as sub-metering, device communication and tariff hunting are included, making the technology more interactive and encouraging greater end-user engagement.

The UK Government has announced a mandate that every UK domestic dwelling should have a smart meter installed by 2020. Discussions on how to implement smart meter communications continue – options include powerline, GSM or, drive-by short-range radio, currently used by some water companies.

Simple solutions can significantly reduce end users’ energy consumption. For example, the electrisave unit and similar energy displays demonstrate the role that consumers’ behaviour has on energy usage. The energy displays enable end-users to take responsibility for the environmental impact of their actions including use of consumer electronics, leaving appliances on standby and leaving lights on. Case Study 9 demonstrates the benefits achieved by the Places for People Group in Milton Keynes.

In order to be classified as Zero Carbon all energy consumed in the home must be generated locally from renewable sources. Zero Carbon homes will usually be connected to the grid to allow the import of energy when required, and the export of surplus energy from renewable sources. In principle, smart meters can monitor and manage the import and export of electricity to the national grid.

Better control over electrical consumption within the home will have significant implications for the energy generation requirements of the national grid. Facilitating peak demand management enables the national grid to reduce its generation requirements – a method often used in commercial energy contracts.

Chip enabled white goods, with the ability to communicate with smart meters, provide a route to more effective energy management. For example, smart meters could ensure that only two of the three primary energy consuming white goods – fridge, washing machine and dish washer – are on at the same time; so called demand management. Monitoring of the use of electricity by individual appliances would also identify the primary consumers of electricity, better informing occupant decisions about which devices to leave on or switch off.

Heat metering is another area where smart home systems can be used to add value. High efficiency, low carbon heating systems work optimally in large-scale installations. However, effective use of communal heating systems is dependent on residents adopting energy efficient behaviour.

This behaviour can be encouraged by charging systems that reward energy efficiency. For example, charging for usage, in contrast to ‘heat with rent’ or standard charging schemes. Case Study 10 demonstrates where effective heat metering has been used to deliver social and economic benefits in a disadvantaged community in Oldham.

### 4.8 Protecting the Building Fabric

Dwellings built to the standards specified in the highest levels of the Code are airtight and heavily insulated. To retain high-energy efficiency performance the fabric of the house should be protected from damage by minimising the need to drill or create holes, during and post construction.

By future proofing the building through the installation of communal aerials, incorporating holes for telecommunications and leaving sealed service voids, the need to damage the building fabric when new building services and smart home systems, such satellite dishes, are installed is reduced. CLG’s Ducting Guide (2) gives guidance on the installation of cable ducting, which will both protect the building fabric and ensure cost effective upgrading of the communications network in the future.

Although not explicitly catered for in the Code, designing buildings with wiring provision and space provision can enable future and cost effective installation of low carbon technologies. After a successful pilot trial, Westlea Housing Association decided to install accessible cornicing in all its following projects to provide ease of access when services needed upgrading and to decrease damage caused by tenants’ own installations. This can include providing blank panels at the correct orientation for the future provision of solar hot water or photovoltaics. See Case Study 6 for more details.
05 Community Applications

The primary focus of this report is on the application of smart home solutions to individual dwellings. Most often, these dwellings are part of a community development. The principles of digital connectivity will be equally beneficial to the wider community as to individual dwellings.

For example:

- Many renewable energy technologies are most effective when developed as large-scale installations to support a community, e.g., wind power. The monitoring and management of this renewable energy can be effectively carried out by community-level communications infrastructure.
- Assistive living services are delivered from a community-level platform.
- Community intranets provide a focal point for people to communicate, encouraging dialogue that might otherwise not take place.

The delivery of digital services and access to the internet from individual homes relies on a community-level communications infrastructure.
In progressing digital connectivity in the UK’s domestic sector, it is essential to consider the housing refurbishment sector, particularly with regard to improving the energy efficiency performance of this stock.

Putting this in context: There are of the order 26 million homes in the UK, 21 million of these in England. Of this stock 50% is over fifty years old, 20% is over one hundred years old; 800,000 homes are vacant, but could be refurbished to make them habitable. 90% of the existing stock will still be in use in 2050. The UK has the oldest housing stock in the developed world.

About 27% of the total energy use in the UK is in homes. The majority of this consumption will be in older domestic dwellings, which are energy inefficient, having a mean SAP rating of 52 against a target of 80. Improving the energy efficiency of housing stock can significantly contribute towards meeting the UK’s carbon emissions reduction target.

An objective of this document is to facilitate discussion about developing the Code for Sustainable Homes, potentially to include smart home solutions for effective monitoring and management of energy and resource use in the home setting.

In progressing this agenda, it is essential to ensure that, where practicable, the application of smart home systems is also carried into the housing refurbishment sector.
ibexcellence (The Centre of Excellence for Intelligent Buildings) is a membership organisation aimed at increasing the uptake of intelligent building solutions in buildings. It provides an open, neutral forum to represent the sector’s views based upon guidance from its members.

This report has been produced as part of the ibexcellence research and communications programme, which is managed and administered by BRE. This programme aims to provide an independent and authoritative evidence base of research results and case study material, to help underpin major investment decisions.

For more information please visit www.ibexcellence.org

Acknowledgements

The Modern Built Environment Knowledge Transfer Network (MBE KTN) is a single, national, over-arching knowledge transfer network for the built environment. It aims to stimulate increased innovation and support its effective implementation in the modern built environment.

MBE KTN works with its members to identify industry challenges, showcase potential innovations, broker new collaborations, facilitate access to funding opportunities and help members connect with each other. It is currently concentrating on five themes that have implications for all sectors of the built environment:

- Energy Efficiency
- Adaptability of Space
- Intelligent Buildings and Infrastructure
- Climate Change Impact
- Life Extension of Structures

Please visit www.mbektn.co.uk to find out more about how to get involved with the MBE KTN community.
Contributors

This report is an output of the ibexcellence Homes & Communities Working Group.

Contributors included:
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- Integer
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- KNX
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- North Hertfordshire Homes
- Origin Housing Group
- Swan Housing Group
- Wates Living Space
- Watford Community Housing Trust

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- KNX-UK
- Places for People
- Sandwell MBC
- Westlea Housing Association
References

1. Teaching Homes to be Green; Green Alliance (London, November 2007))

Appendix 1: Case Studies

A1: Case Study 1
Housing Solutions Group,
Alpine Close Development, Maidenhead

Heat from a centralised boiler system is distributed to each unit, where intelligent controls manage the heating load in relation to room temperature. If the room is already warm enough the heating will not come on, even though it may be time to do so.

Heat metering and a building management system allow Housing Solutions Group to diagnose and manage the system from their own offices.

Remote utility metering has been installed where possible, allowing greater control and transparency of costing for both supplier and tenant.

This has resulted in gas bills as low as £55 per annum in one-bedroom flats.

A2: Case Study 2
KNX Controls in Switzerland

A KNX project by DOMO Energie in Switzerland demonstrated a 48% reduction in thermal energy demand and a 40% reduction in electrical energy demand. This was achieved on a 340 m² family home in Piudoux, Lake Geneva. Electrical energy savings were achieved through automatic lighting controls and motion & light sensors.

Heating is provided through a wood pellet boiler. Each room is fitted with a multi-function operating terminal including a temperature sensor and LCD display for individual room control of temperature, lighting and the shading system. The occupancy sensor changes the temperature set point from "comfort" to "standby". Standby room temperatures can be set centrally. Opening windows will lower the temperature set point.

Three daylight sensors deliver threshold values for automatic lighting controls, which control ceiling mounted lights, as well as stand and table lamps. At night, blinds close fully and lighting is set to user defined lighting levels. At dawn, the blinds open automatically.

A3: Case Study 3
BASF House, University of Nottingham
(Research & Test House)

The BASF house is a collaborative research and dissemination project between the School of the Built Environment, University of Nottingham and BASF. The objective of the project is to explore the application of the German Passivhaus Standard to other countries in Europe.

The design concept is simple, resulting in a compact floor area. The house makes extensive use of passive solar design. The north, east and west walls are highly insulated, with the minimum number of openings compatible with acceptable daylight levels. The southern elevation has a fully glazed two-layer sun space. A number of opening apertures of various configurations ensure that the glazed screens to the sunspace can be opened or closed to assist passive heating or cooling.

Designed as a conventional dwelling, the house will be occupied by University staff or students. Careful monitoring of the building's performance during occupation will provide vital data on the advantages and disadvantages of living in a highly insulated, airtight structure.

Selection of the smart home controls system was constrained by cost – mirroring the reality of system selection in the market place. The selected system had to be:

- Affordable
- Flexible
- Expandable.

The system had to demonstrate a long maintenance life, with the facility for easy upgrading and continuing supplier support. This is a critical issue. If an integrated control system ceases to be supported and becomes non-operational, the performance of the house will be significantly affected. Replacement of integrated systems is costly, messy and disruptive, and therefore unlikely to be carried out by the homeowner, occupier or landlord.

Using the selection criteria the WebBrick® system was chosen to monitor and control:

- Ventilation
- Heating
- Lighting

It can additionally interface with the security system, blinds and entertainment systems but in this particular house, this was not considered essential.

Smart meters were installed to measure the use of resources in the house, i.e. electricity, with the data being presented on a touch screen panel mounted in the kitchen. This touch screen also provides a user interface with a menu of options for controlling the home.

Similarly home PCs, office PCs and many 'off the shelf' internet gadgets like smart phones, PDAs and internet phones can be used to securely control and monitor the Eco-house. This allows for remote monitoring and management of the house from anywhere in the world accessible to an IP network.

Lighting in the house system is provided by low energy, low voltage LED (light emitting diode) lighting technology.

Monitoring of the house continues, and performance data should be available during 2009.
A4: Case Study 4
Refurbishment of an 18th Century Cottage (Refurbishment)

A cottage in Derbyshire, left vacant for more than 20 years, and virtually derelict, was renovated to modern standards. The renovations included installation of KNX building services control technology.

The cottage – its oldest part dating from 1799 – is now a single dwelling that has two reception rooms, a conservatory and three bedrooms. KNX system devices control the building services in the cottage, including:

- Lighting
- Heating
- Security
- Audio

These facilities meet the requirements of a contemporary lifestyle, while retaining a traditional environment.

The installation was carried out jointly by the home-owners and a local electrician. The work spanned fifteen months, using a well-developed plan. Installation and commissioning of the KNX systems relied on use of the ETS-KNX programming tool.

The cottage has forty-five dimmed and switched lighting circuits for setting moods for each room. The controls also allow lights to be incorporated into other features of the house including:

- A welcome home function, incorporating a motion sensor by the front door.
- A ‘discreet’ scene set for the bedrooms including the facility to set lights at a very low level, providing a low level illuminated pathway, eliminating the need to switch on full lighting.
- Water based underfloor heating throughout the entire cottage in nine zones is controlled using thermostatic light switches, removing the need for traditional wall thermostats, which can be unsightly.
- The controls lower night-time temperatures and - when the house is unoccupied - the set point. This results on significant energy cost savings for space heating.

The controls installation is remotely accessible by internet connection from anywhere in the world using an IP addressable controller. The installation has many other features such as direct heating and lighting control, security monitoring, remote diagnostics, IP camera viewports, email transmissions for security breaches or activated smoke detectors.

A5: Case Study 5
A Multi-function House Installation (Multi-function Installation)

The refurbishment of Hidden Streams, Sussex included rewiring and integration of KNX controlled building services products. The KNX installer’s brief was to provide control for internal & external lighting, heating, blinds & curtains, and a multi-room music system.

The installation includes a series of four pre-set lighting scenes for each room. Each scene-set is programmed to switch and dim lights to achieve different ambiences. This facility is available in each room. For example, by activating a scene-set, lights can be set to fade in gradually. Scenes are easily adjusted via the switch plate in the room and can be permanently stored. In some rooms, local control of individual lights is also provided - for example at the desk in the study, or at the bedside.

Heating control is split into 12-separate zones distributed across all rooms in the house. In the older part of the house, traditional radiators are fitted with KNX radiator valve actuators that open and shut the radiator dependent upon requirement for heat. In the newer parts, the same types of valve actuators are fitted to the under floor heating manifold. The valves can be set to ramp open or shut, the gradient of the ramp depending on the difference between internal and external temperatures.

Roller blinds and curtains are also controlled by the KNX system. The blinds shut automatically at dusk and open again under timer control in the morning.

Additional features include the scene setting of the external lights via an LCD touch screen. This also provides timed control of the heating and simple access to shut the house down for holidays. At the exit doors and in the master bedroom, there are buttons that will shut off all the lighting in the house to prevent unnecessary energy use.

A6: Case Study 6
Westlea Housing Association; Cherhill (Social Housing)

The project consisted of two, three-bedroom houses, replacing a pair of semi-detached houses destroyed by fire. Westlea Housing Association used the project to develop knowledge and skills, enabling them to provide tenants with better homes.

The general space standards, easily accessible storage space, effective insulation, solar hot water heating and consequent low utility bills impressed residents.

Extensive energy and temperature monitoring, funded by the Housing Corporation, showed internal temperatures were very stable, even with external temperatures below freezing. The project’s results showed residents are paying around 50% less for energy by comparison with their previous homes.

Westlea Housing Association selected a reliable maintenance contractor, training them in the maintenance of the innovative systems. There have been no exceptional maintenance issues with the two homes.
A7: Case Study 7
Sandwell MBC – Lyng Estate (Social Housing)

This project was a 15-unit pilot project of six, one bed apartments, six two bed flats and three houses. Sandwell Metropolitan Borough Council (MBC) wanted to challenge the perceived mediocrity in house building practice, and so raise the expectations of the public regarding social housing. All parties involved in delivery of the project signed up to a partnership charter. Contracts were awarded to contractors committed to partnering and the principles of intelligent and green innovation.

Analysis showed that the project came in at £689 per m², c.6% above the cost for traditional build social housing. The cost analysis excluded features such as solar spaces, grey water recycling, passive stack ventilation and solar water heating, as these are not standard practice in social housing. This cost was in the upper quartile of traditional build social housing, which at the time ranged from £565 to £690 per m². The use of modern methods of construction resulted in a reduced construction period and an estimated one-off cost saving of c.£25,000.

The scheme was popular with residents, who enjoy living in the properties. They have also reported lower utility bills. CCTV, grey water recycling and solar hot water heating have proved particularly popular.

This pilot project has not been without its problems. A key factor for the long-term success of any innovative project is correct maintenance. To achieve this it is essential that maintenance staff are involved with the project at an early stage.

In Sandwell, the maintenance team felt they inherited problems which they were not consulted about. The difficult issues around delivering housing innovation in Sandwell were highlighted by an Audit Commission report. Against this background, the introduction and implementation of successful innovation is especially challenging. Negative comments from residents have centred on maintenance issues, with residents identifying staff turnover as a major problem.

Westlea Housing Association have now integrated the innovative features of the Cherhill project into their standard practices, incorporating features like high levels of insulation and, leaving voids for the easy retrofitting of structured cabling. Westlea subsequently completed a 54-home development at Calne, Wiltshire incorporating many of the features of the Cherhill project.

Key Innovations

- Intelligent Technologies
  - Whole house and accessible cabling for use with energy management, telephony, computers, and CCTV security. The cabling makes all services available in any room.
  - Simple and precise controls for heating, reducing energy wastage.
  - Integrated lighting controls allowing for control of all lights from a single point.
  - Movement sensors linked to the lighting system to provide unobtrusive floor level light paths for night-time wandering or in the event of fire.
  - Off-peak electric storage heaters linked to motion sensors which only release heat when movement is detected in the room.
  - CCTV cameras on both front and back doors and motion initiated lights allow pictures of visitors to be shown on the TV screen.
  - Emergency lights at the top of each flight of stairs and in the dining area automatically operated in the event of a power failure.
  - Lights can be detached and used as torches to find the way to the fuse box in the event of a blown fuse

- Environmental
  - Water savings of over 40% through the use of grey water recycling
  - Recycled water-buts collect rainwater for garden irrigation
  - Fan-assisted passive stack effect ventilation system
  - Use of recycled materials, eg railway sleepers and telegraph poles for retaining walls, and plastic from milk cartons as boundary fencing
  - Low energy light fittings
  - Materials like the Western Red Cedar cladding selected for sustainability, low embodied energy, long life and low maintenance
  - Rooftop solar water heaters providing free hot water for the houses
  - Use of solar spaces as a temperature barrier between the insulated house and the external atmosphere, maintaining heat in the winter and keep the houses cool in the summer

- Design & Construction Innovation
  - Limited wet-trades
  - Off-site fabrication of timber panels meant that the superstructure of the homes took only two weeks to erect
  - Recycled newspaper, cellulose insulation
  - Central service ducts carrying wet and dry services
  - Removable ducts at skirting and ceiling level allowing for easy access for installation and modification of main service routes
A8: Case Study 8
Residential Buildings in Singapore

Delmatic Lighting Management applied energy efficient lighting management to public housing blocks in Singapore, where a pioneering project has achieved 70% energy savings while enhancing lighting control and maintenance.

Prior to the refurbishment the residential blocks had 100% lighting on throughout the night and required maintenance engineers to visit and tour the blocks on a regular basis to identify and replace failed lamps. This approach was inefficient in terms of both energy and manpower.

The local authority was keen to reduce energy consumption and increase the standard of service on offer to its residents. The solutions had to be retrofitted into occupied buildings, with minimal disruption and be scalable to enable central control and monitoring of multiple buildings.

Delmatic used Dali technology to connect multiple luminaires on a single bus-wire, enabling each to be switched, dimmed and monitored individually. Lon technology was used to connect multiple Dali systems within a building or across a site for remote monitoring and management.

A lighting controller addresses and controls the ballasts, optimises the light output to achieve energy savings, enables lighting levels to be configured to suit the building orientation and highlights lamp failures to ensure rapid repair.

Energy savings of 70% were achieved through the new system. 30% of these savings were achieved through installing more efficient ballasts. The remaining 40% savings were achieved through dimming controls reducing lighting levels during the night.

A9: Case Study 9
Places for People Milton Keynes

A smart meter trial carried out by the Places for People Group in Milton Keynes produced annual savings of up to £80. In January 2006, 50 Electrisave smart meters were installed at Broughton Atterby in Milton Keynes. The meters helped the residents to reduce their electricity consumption by 13 – 15 per cent compared with the other homes on the estate. Household carbon emissions were cut by approximately 233 kg per year and electricity bills were cut by £60–£80 per annum.

A10: Case Study 10
Heat Metering in Oldham to Combat Fuel Poverty

First Choice Homes, Oldham used Switch 2 energy solutions to provide heat metering, control and prepayment equipment for 615 homes in the St Mary's District Scheme. The units use Smart Card technology which allows consumers to buy as much or as little heat as they require. Since all the infrastructure was paid for by the service provider there was no capital expenditure by the landlord. The scheme provided affordable warmth for the residents and increased control led to CO₂ emissions being cut.

Key Innovations

- Intelligent Technologies
  - Adaptable cabling systems allowing for easy and inexpensive future upgrade
  - Digital satellite, digital terrestrial and conventional analogue TV signals provided from one centralised satellite dish and aerial system
  - Every room except the bathroom has two phone lines allowing residents to dial-up to the internet and to make calls simultaneously
  - A single central boiler system used to meet the low heat demand of the highly insulated homes
  - Intelligent controls judging the optimum time for the boiler to operate, while heat metering and thermostatic radiator valves in each dwelling provide environmental control for the individual tenant
  - Solar water heaters providing domestic hot water to a maximum of 75°C. This is linked to a boiler which is turned on by a sensor if the heater draws insufficient solar energy to reach the required temperature
  - Low-energy light fittings, but without integrated lighting systems as these were too expensive at the time of construction

- Environmental Technologies
  - Passive stack ventilation in kitchen and bathrooms, removing the need for electrical extractor fans
  - A grey water system, which treats and recycles water from the bath to be re-used for toilet flushing. In addition, this system is topped-up by rainwater, via a diverter at the base of the rainwater downpipes

- Design & Construction
  - Timber wall panels filled with recycled cellulose insulation, providing speedy construction and also excellent SAP energy efficiency rating
  - Western red cedar cladding, alternating with acrylic render panels to create visual interest in a location with a strong tradition for brick build
  - Low maintenance aluminium roofing adding visual impact
  - Glazed entrance lobbies to the apartments creating an attractive solar space or winter garden, making any would-be burglars more visible. Solar double-storey conservatories provide the same effect for the houses
  - Clearly defined pathways through the buildings for electrical wiring and cabling for data, voice and TV
Ayrshire Housing Association – Home
Monitoring for Sheltered Housing
(Assistive Living)

Internet-enabled sheltered housing in the village of Kirkmichael, Ayrshire, was the output of a project supported by the Technology Strategy Board (TSB). The housing was designed to support the needs of the elderly and those with special needs.

Ayrshire HA installed smart electronics in two internet-enabled terraced houses, including a variety of sensors. The installations included:

- Air temperature sensors
- Air quality sensing (carbon dioxide and relative humidity)
- Smoke detection
- Flood detection (below sinks)
- Panic buttons
- PIR sensors and door-open sensors.

The sensors relay information to carers on environmental conditions and hazards. In the case of hazards, automatic messages are sent to mobile telephones of carers. Monitored hazards range from those that present:

- An immediate threat, e.g., smoke, panic button, flooding, intrusion
- Less immediate issues, e.g., hypothermia alert
- Longer-term problems such as detection of the need for maintenance of heating and ventilation, e.g., abnormal boiler flow and return temperatures or high humidity levels.

Both dwellings have broadband internet connection. Each dwelling has a smart box with a dynamic IP address. Information from the smart box is relayed to a remote server that carries out analysis of data. The server transmits the analysed information to a fixed IP address, accessed by users and carers through the internet. Most sensors are wireless, communicating directly with the smart box – using signal boosters where these are necessary.