Energy efficient fixed appliances and building control systems

Primary Research

NHBC Foundation
Housing research in partnership with BRE Trust

ZERO CARBON HUB

F 43

NHBC Foundation
NHBC House
Davy Avenue
Knowlhill
Milton Keynes
MK5 8FP
Tel: 0844 633 1000
Email: info@nhbcfoundation.org
Web: www.nhbcfoundation.org

Visit the NHBC Foundation blog at http://nhbcfoundation.blogspot.com

Follow us on Twitter @nhbcfoundation

Research undertaken by:

Ross Holleron, Principal Consultant and Adam Tilford, Senior Consultant, BRE.

NF 43
Published by IHS BRE Press on behalf of the NHBC Foundation
July 2012
ISBN 978-1-84806-182-8

Energy efficient fixed appliances and building control systems

Primary Research

July 2012

NHBC Foundation
Housing research in partnership with BRE Trust

Zero Carbon Hub

About the Zero Carbon Hub

The Zero Carbon Hub was established in the summer of 2008 to support the delivery of zero carbon homes from 2016. It is a public/private partnership drawing support from both Government and the industry and reports directly to the 2016 Taskforce.

The Zero Carbon Hub has developed five workstreams to provide a focus for industry engagement with key issues and challenges:

- Energy efficiency
- Energy supply
- Examples and scale up
- Skills and training
- Consumer engagement.

To find out more about these workstreams, please visit **www.zerocarbonhub.org**. If you would like to contribute to the work of the Zero Carbon Hub, please contact **info@zerocarbonhub.org.**

Contents

Glossary

Allowable solutions	The measures permitted for dealing with residual CO_2 emissions remaining after taking account of carbon compliance measures.
British Electrotechnical and Allied Manufacturers' Association (BEAMA)	BEAMA is a national grouping which represents the interests of the UK's electrotechnical companies.
Building control systems	Systems installed during construction that reduce regulated emissions below the level assumed by the Standard Assessment Procedure (SAP). They are commonly used to optimise the performance of lighting, space and water heating, and ventilation.
Building Research Establishment Domestic Energy Model (BREDEM)	A model revised on an annual basis that estimates energy consumption in dwellings, including estimates for space heating, water heating, cooking, and lights and appliances.
Carbon dioxide (CO_2)	An invisible odourless gas which is a by-product of the oxidation or burning of organic matter such as coal, gas, oil and wood. It is a significant contributor to climate change.
Carbon Emissions Reduction Target (CERT)	A Department of Energy and Climate Change (DECC) programme that requires gas and electricity suppliers to achieve targets for a reduction in CO_2 emissions generated by dwellings. Further details are available from www.ofgem.gov.uk and www.decc.gov.uk.
Carbon compliance level	The minimum level of carbon reductions, compared to Building Regulations Part L 2006, to be achieved onsite (through energy efficiency and any Low and Zero Carbon energy generation onsite) and by direct connection of onsite or offsite Low and Zero Carbon heat to the building. For example a 70% carbon compliant home would emit 70% less CO_2 than that permitted by Approved Document L1A 2010[1, 2].
Colour rendering index	A quantitative measure of the ability of a light source to reproduce the colours of objects when compared to an ideal or natural light source.
Compact Fluorescent Lamp (CFL)	An energy efficient type of fluorescent lamp which plugs into a small dedicated lighting fixture within a dwelling.
Code for Sustainable Homes (CSH)	UK Government-owned environmental assessment method for certifying and rating new homes. Full details are available from www.communities.gov.uk/planningandbuilding[2] and www.planningportal.gov.uk.
Department of Communities and Local Government (DCLG)	A department of the UK Government with responsibility for setting policy on local government, housing, urban regeneration, planning, and fire and rescue. DCLG is the owner of the Code for Sustainable Homes.
Department of Environment and Climate Change (DECC)	UK Government department with responsibility for all aspects of energy policy, and for tackling global climate change on behalf of the UK. Further details are available from DECC's website (www.decc.gov.uk).
Department for Environment, Food and Rural Affairs (DEFRA)	Department of the UK Government with responsibility for securing a healthy sustainable environment in which we and future generations can prosper. Further details are available from DEFRA's website (www.defra.gov.uk).
Dwelling Emission Rate (DER)	Annual CO_2 emission in kg per m^2 of building floor area. DER is based on the energy used for space heating, hot water, pumps, fans and lighting as calculated using SAP and reflects the chosen fuel used for these applications. Compare with the Target Emission Rate.

Efficacy	The ratio between the luminous flux produced by a lamp (in lumens) and the total power consumed by both the lamp and its associated control gears (in watts). It is a measure of the overall effectiveness of any lamp in transforming electricity into light.
Emission factor	The quantity of CO_2 emitted to the atmosphere as a result of using a unit (1 kWh) of energy at the dwelling level. Emission factors vary depending on the carbon intensity of each fuel, and consider any conversion from another form of energy prior to use (eg electricity generation) and the distribution of fuel or energy to the point of use (eg gas distribution, electrical transmission losses). Emission factors are given in Table 12 of *The Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings*[3].
Energy efficient fixed appliances	Advanced non-portable devices, such as fixed heating and ventilation systems, that are frequently installed during construction and have a reduced energy demand. This may include systems that fully or partly generate their own energy (eg new Low and Zero Carbon technologies) to those systems which recover waste energy (eg heat recovery ventilation systems).
Energy Saving Trust (EST)	The EST provides independent evidence-based policy analysis on energy efficiency, small-scale renewable technologies and clean, low carbon transport.
Energy Using Products Directive (EuP)	European legislation for improving the environmental performance of energy-using products.
Fabric Energy Efficiency Standard (FEES)	FEES is a performance-based metric that specifies a minimum fabric energy efficiency of 46 kWh/m^2/for semi- and detached houses and 39 kWh/m^2/year for mid-terrace houses and flats. An allowance for higher energy consumption has been made for detached houses in order to maintain a similar fabric specification across all built forms; however, an enhanced fabric is still likely to be required[2].
Light Emitting Diode (LED) lamp	An energy efficient semiconductor-based lamp which plugs into either a small dedicated lighting fixture within a dwelling or, if the LED driver is incorporated into the lamp, one of the range of traditional lamp holders used in housing.
Low energy lights	Generic term for energy efficiency lighting. In a domestic context this is likely to mean either Compact Fluorescent Lamp or Light Emitting Diode technology.
Low and Zero Carbon (LZC) heat	Heat generated using Low or Zero Carbon technologies. Low and Zero Carbon heat may be generated within individual dwellings or generated at a central plant and supplied to homes via a heat distribution network. This may be on a small scale for covering a single development or on the scale of district heating, covering sections of an entire city.
Low and Zero Carbon (LZC) technologies	Technologies that provide energy without creating the CO_2 emissions associated with traditional fossil fuel-based energy technologies. They may be those technologies that are generally considered renewable sources of energy such as solar electric, wind power, solar water heating, and more efficient ways of using fossil fuels – for example combined heat and power, or new high-tech solutions such as fuel cells.
Luminaire	An electrical device used to create artificial light or illumination incorporating both the light source (eg incandescent filament light bulb, Compact Fluorescent Lamp or Light Emitting Diode-based lamp) and the light fitting along with an electronic driver required to operate the light source. When assessing the efficiency of lighting it is the overall luminaire efficiency that should be considered.
Mechanical Extract Ventilation (MEV)	A fan-driven ventilation system that extracts air to the outside from the areas of a dwelling where moisture is generated. Air is replaced in the dwelling through infiltration.

Mechanical Ventilation with Heat Recovery (MVHR)	A balanced fan-driven ventilation system for the whole dwelling, which both supplies fresh air to, and extracts stale air from, the dwelling. A heat exchanger is incorporated into the system which uses the warm exhaust air to pre-warm incoming fresh air.
Passivhaus	A voluntary standard applicable to both domestic and non-domestic buildings, originating in Germany. Its design methodology focuses on delivering very low energy buildings by reducing the primary energy use before installing renewables. Buildings are designed to achieve a space heating requirement of 15 kWh/m^2/year or less and a total primary energy consumption of 120 kWh/m^2/year or less.
Passive Flue Gas Heat Recovery (PFGHR)	A means of recovering latent heat from the flue gases of condensing boilers. The flue gases pass through a secondary heat exchanger which is used to pre-heat the cold water supply thus the savings are targeted at the energy used to heat domestic hot water.
Photovoltaic (PV) panels	Panels of solar cells made of semiconductor materials that generate direct current electricity from solar radiation using the PV effect. A number of panels can be assembled into an array and coupled with an inverter (to convert direct current to alternating current) in order to supply useful energy to dwellings.
Positive Input Ventilation (PIV)	A fan-driven ventilation system for the whole dwelling that is typically mounted in the roof space and supplies air into the dwelling via a central hallway or landing. This creates a slight positive pressure in the dwelling.
Pumps and fans	Devices for moving fluids around a dwelling, such as pumps for hot water heating systems and fans for air ventilation systems.
Real Time Displays (RTDs)	Electrical devices that use sensors to detect the amount of energy a dwelling is currently using and sends this data wirelessly to an accessible visual display that allows occupants to see how much energy they are using.
Regulated CO_2 emissions	Carbon dioxide emissions from space and water heating, lights, pumps and fans but not from cooking and appliances.
Relative Humidity (RH)	The ratio of water vapour in the air to the maximum amount that the air can hold at a specific temperature, expressed as a percentage.
Standard Assessment Procedure (SAP)	The Government's approved methodology for rating the energy performance of domestic dwellings.
SAP Appendix Q	A methodology for assessing the energy performance of new technologies and advanced versions of existing technologies for inclusion in SAP assessments. Further details are available from the SAP Appendix Q website (www.sap-appendixq.org.uk).
Secondary heating	AD L1A[1] of the Building Regulations and SAP 2005[3, 4], which is used to demonstrate compliance with AD L1A, assume a domestic heating regime in which 90% of the space heating required by a dwelling is supplied by the central heating system (eg gas boiler and radiators) and the residual 10% is supplied by a secondary system such as a gas fire in the living room. In the absence of such a fixed secondary heating system being specified, it is assumed that portable direct acting electric heaters are used. AD L1A 2010 and SAP 2009 remove this assumption.
Smart meters	A utility meter that provides more detailed information than a conventional electricity or gas meter, ie energy use per time period. Smart meters may also communicate the information collected to a local display (see *Real Time Displays*) or service provider for monitoring and utility billing purposes.

Solar-assisted Positive Input Ventilation	Similar in principle to Positive Input Ventilation, however the supply air is pre-heated by passing though a specially designed solar panel before being fed into the dwelling.
Solar hot water	A type of Low and Zero Carbon fixed appliance where water is heated through the use of solar energy. It is used to provide domestic hot water and occasionally space heating to buildings.
Specific fan power	A measure of the energy efficiency of a fan system. Commonly, used in SAP calculations for ventilation systems.
Target Emission Rate (TER)	The calculated maximum allowable CO_2 emissions per m^2 for a building. It is calculated using the SAP methodology and includes estimates for the energy used by space heating, hot water and lighting. Compare with the Dwelling Emission Rate.
The Electric Heating & Ventilation Association (TEHVA)	The trade association with responsibility for promoting electric heating, hot water and mechanical ventilation products and systems.
United Kingdom Accreditation Service (UKAS)	The sole national accreditation body recognised by Government to assess, against agreed national standards, organisations that provide certification, testing, and inspection and calibration services. UKAS accreditation demonstrates competence, impartiality and performance capability of the evaluators.
Waste Water Heat Recovery (WWHR)	A means of recovering some of the heat energy content of waste water discharged from buildings (generally shower waste water in a domestic context), which is then used to pre-heat the incoming cold water supply thus reducing the energy required to heat domestic hot water.
Whole house shutdown	A system that allows the occupants of a home to conveniently and reliably turn off the power to electrical items (lighting and appliances) on leaving the dwelling, and turn it on again when they return.
Zero carbon homes (DCLG definition, December 2008 incorporating Budget announcements, March 2011)	Zero carbon homes are those built in such a way that, after taking account of emissions from space heating, ventilation, hot water and fixed lighting, and exports and imports of energy from the development will achieve a 100% reduction in CO_2 emissions when compared to homes built to AD L1A 2006. It is proposed that, to meet the zero carbon homes standard, homes should: ■ Be built with high levels of energy efficiency. ■ Achieve at least a minimum level of carbon reductions through a combination of energy efficiency, onsite energy supply and/or (where relevant) directly connected low carbon or renewable heat. ■ Choose from a range of (mainly offsite) solutions for tackling the remaining emissions. Modelling undertaken for this report includes both regulated and unregulated energy use. This is different to the Government's definition of a zero carbon home (detailed in the Budget announcements of 2011) which only considers regulated energy use.

About the NHBC Foundation

The NHBC Foundation was established in 2006 by the NHBC in partnership with the BRE Trust. Its purpose is to deliver high-quality research and practical guidance to help the industry meet its considerable challenges.

Since its inception, the NHBC Foundation's work has focused primarily on the sustainability agenda and the challenges of the Government's 2016 zero carbon homes target.

The NHBC Foundation is also involved in a programme of positive engagement with Government, development agencies, academics and other key stakeholders, focusing on current and pressing issues relevant to the industry.

Further details on the latest output from the NHBC Foundation can be found at www.nhbcfoundation.org.

NHBC Foundation Advisory Board

The work of the NHBC Foundation is guided by the NHBC Foundation Advisory Board, which comprises:

Foreword

This primary research report examines the range of energy efficient fixed appliances and building control systems that are either currently available, or are under development and may be available before 2016. It considers how these may be introduced into new homes.

The report considers a variety of technologies that would influence the reduction in energy consumption and associated CO_2 emissions for a typical home built in 2016, and identifies those that show merit of further investigation by designers, house builders and the wider industry.

Importantly, the research shows that a number of technologies offer significant potential for saving energy and reducing CO_2 emissions.

The research also found that, contrary to what was envisaged at the start of the project, many of the technologies can, or may in future, be considered via the 'energy efficiency and carbon compliance' aspects of the zero carbon new homes policy.

As we head towards the zero carbon future for new homes, and begin to address the huge challenge of reducing energy consumption and achieving carbon emission savings in our homes, it is clear that the correct choice of energy efficient technologies is likely to make a valuable contribution.

I hope that you will find the report both useful and informative.

Rt. Hon. Nick Raynsford MP
Chairman, NHBC Foundation

Executive summary

This report describes a study entitled 'energy efficient fixed appliances and building control systems'.

The study was commissioned by the NHBC Foundation and carried out by BRE. It involved:

- Understanding what energy efficient fixed appliances and building control systems are currently available or are under development and may be available in 2016 in order to inform debate on the 2016 zero carbon new homes policy.
- Gauging the significance of these technologies relative to the likely CO_2 emissions for a typical home built in 2016.
- Identifying those technologies that merit further investigation by designers, house builders and the wider industry.

The report presents the findings of this study and highlights the various issues to be considered in the implementation of energy efficient fixed appliances and building control systems. It was found that a number of technologies analysed by the study offer significant potential for saving energy and thus reducing CO_2 emissions. The study also found, contrary to what was envisaged at the start of the project, that many of the technologies can, or may in future, be considered via the energy efficiency and carbon compliance aspects of the zero carbon new homes policy.

Of the technologies assessed to have the greatest relevance in achieving net zero CO_2 emissions over the course of a year, the two that stand out as offering the greatest CO_2 emission reductions are whole house shutdown (19% reduction) and Waste Water Heat Recovery (6.8% reduction).

1 Introduction

The NHBC Foundation commissioned BRE to research the potential role that energy efficient fixed appliances and building control systems might play within the context of the UK Government's proposed zero carbon home definition as originally defined in December 2008[5, 6]. It is in this context in which the modelling work for this project was carried out, to take into consideration CO_2 emissions from both regulated and unregulated energy use, examining all CO_2 emissions resulting from running a home. Budget announcements in March 2011 have subsequently redefined the policy with unregulated emissions (those emissions resulting from the use of plug-in appliances) no longer a part of the policy. A summary of the approach taken for this project is as follows:

- The zero carbon new homes policy is based upon improved energy efficiency through reducing energy demand for space and water heating, lights and appliances as far as practicable across the residential new build sector. This will be achieved in the first instance by conforming to the Fabric Energy Efficiency Standard (FEES), although could be taken further, eg to the Passivhaus standard. This is represented in Figure 1 as the base of the triangle: energy efficiency. A higher basic energy efficiency will reduce the requirement for Low and Zero Carbon (LZC) technologies needed in order to achieve carbon compliance.

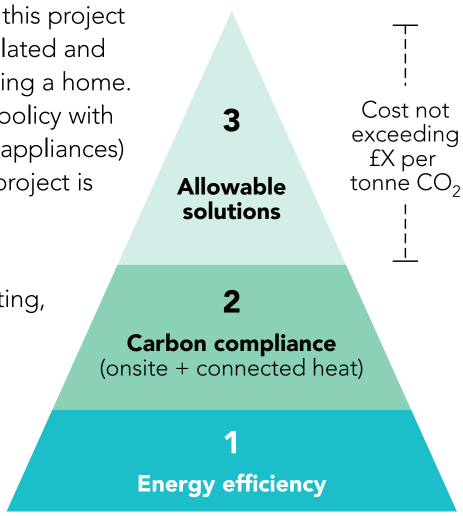


Figure 1 The zero carbon hierarchy[5]

- Following demand minimisation through fabric energy efficiency, all homes will be expected to achieve carbon compliance through a minimum percentage reduction in CO_2 emissions from regulated energy use, when compared to Building Regulations Approved Document Part L requirements. At the time the modelling work was carried out, this was taken to be a 70% reduction of CO_2

emissions compared to AD L1A 2006[1] requirements. This is achieved though a combination of onsite LZC technologies and, where appropriate, LZC heat from an offsite source or network (eg district heating systems).

- Finally a series of allowable solutions that may include energy efficient fixed appliances and building control systems, refurbishment of existing stock and financial investment in energy infrastructure can be employed to achieve net zero CO_2 emissions. For modelling purposes this was taken as a reduction of circa 150% compared with Part L 2006 emissions. This figure includes both regulated and unregulated emissions and varies with built form (eg perimeter-to-floor area ratio) Use of this figure pre-dates 2011 Budget announcements when emissions resulting from unregulated energy use were excluded from the zero carbon new homes policy.

The primary objectives for this report were to:

- Understand what energy efficient fixed appliances and building control systems are under development, or are currently available, that may be of interest to house builders in 2016, in order to inform debate on the 2016 zero carbon new homes policy.
- Gauge the significance of these improvements relative to expected new build CO_2 emissions for a typical 2016 home.
- Prioritise which technologies merit further investigation by designers, house builders and the wider industry.

This research has been approached in two main stages: an industry scoping exercise followed by an assessment based on both technical and wider policy/consumer issues. It is important to consider issues beyond simply the carbon agenda, as vital as that is, when assessing the potential for certain appliances and control technologies to become significant by 2016.

The following sections provide a brief overview of the assessment matrix developed and the Standard Assessment Procedure (SAP) modelling basis for estimating CO_2 reductions. This is followed by a summary of the industry discussions undertaken, and then finally a review of the technologies identified for further consideration.

1.1 Context of CO_2 emissions from a 2016 home

The Government's zero carbon hierarchy approach first requires energy efficiency to be addressed. The starting point has therefore been taken as the FEES. Following this, a 70% reduction in the Dwelling Emission Rate (DER) compared with the Target Emission Rate (TER) has been used as the level to be achieved onsite. This is illustrated in Figure 2 and may be achieved by improving aspects of the fabric such as airtightness, improving building services efficiencies and adding renewable technologies. The performance of this 70% carbon compliant home is well in advance of typical housing at the time of writing. It is onto this predicted 2016 baseline that the allowable solutions are added; it is therefore important for any technology being considered in this study to be assessed within this future context. At the time of writing the Government has not yet published the final definition of carbon compliance, however, it is understood that Zero Carbon Hub recommendations[7] (*Carbon Compliance – Setting an Appropriate Limit for Zero Carbon New Homes*) will form the basis for future consultations on changes to the Building Regulations (*Budget – Plan for Growth*)[8].

In order to provide a clear baseline for comparison, a 70% carbon compliant home has been modelled using SAP. This modelled home has regulated emission reductions of 70% when compared to a home built to AD L1A 2006 requirements. SAP 2005 was used to generate a Part L 2006 TER for a typical 88.8 m^2 semi-detached house, using gas as its primary fuel.

This typical house was then remodelled in SAP 2009, using NHER SAP 2009 Preview 1.4[6] in order to generate:

- A fabric specification that meets the FEES.
- An indicative specification that might be seen in a 70% carbon compliant home, as envisaged at the time of writing. This specification incorporates features such as Mechanical Ventilation with Heat Recovery (MVHR) and renewables in order to achieve a 70% reduction in the DER.

The typical house specification was detailed in Table 1 and is designed to align with the expected onsite requirements of the UK Government's zero carbon homes policy. Figure 2 illustrates the energy use categories and their resultant CO_2 emissions expected at the time of writing in order to meet 70% carbon compliance (against AD L1A 2006). It includes an assumption of 3 m² of solar thermal and 1.45 kW peak output photovoltaic (PV) panels within the design specification.

Figure 2 shows the resultant CO_2 emissions from energy use in the main categories considered within the 2009 version of SAP[6] and helps the reader to appreciate which areas may offer the greatest potential for CO_2 savings. It is based on a typical house described in Table 1, the fabric of which meets the FEES for semi-detached houses.

Table 1 **Indicative 70% carbon compliant home**

Target Emission Rate (from SAP 2005)	22.85
Dwelling Emission Rate (from SAP 2009)	6.8
Improvement	70.24
Fabric Energy Efficiency Standard	45.51 kWh/m²/year
Feature	
Floor area	88.8 m² (two storey)
Main fuel and heating	Gas, condensing boiler
Walls	0.15 W/m²K
Floor	0.15 W/m²K
Roof	0.12 W/m²K
Windows	1.4 W/m²K
Detailing	y -value = 0.04
Airtightness	3.00 m³/h/m²
Ventilation	Mechanical Ventilation and Heat Recovery (specific fan power 0.6 and 90% Relative Humidity)
Domestic hot water cylinder	250 l dual coil
Lighting	100% Compact Fluorescent Lamps
Photovoltaic	1.45 kWp (south, 30°)
Solar thermal	3 m² flat plate (south, 30°)

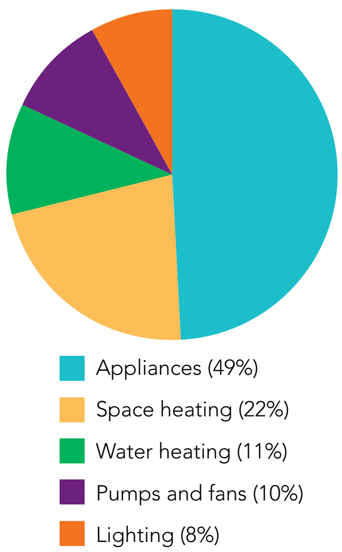


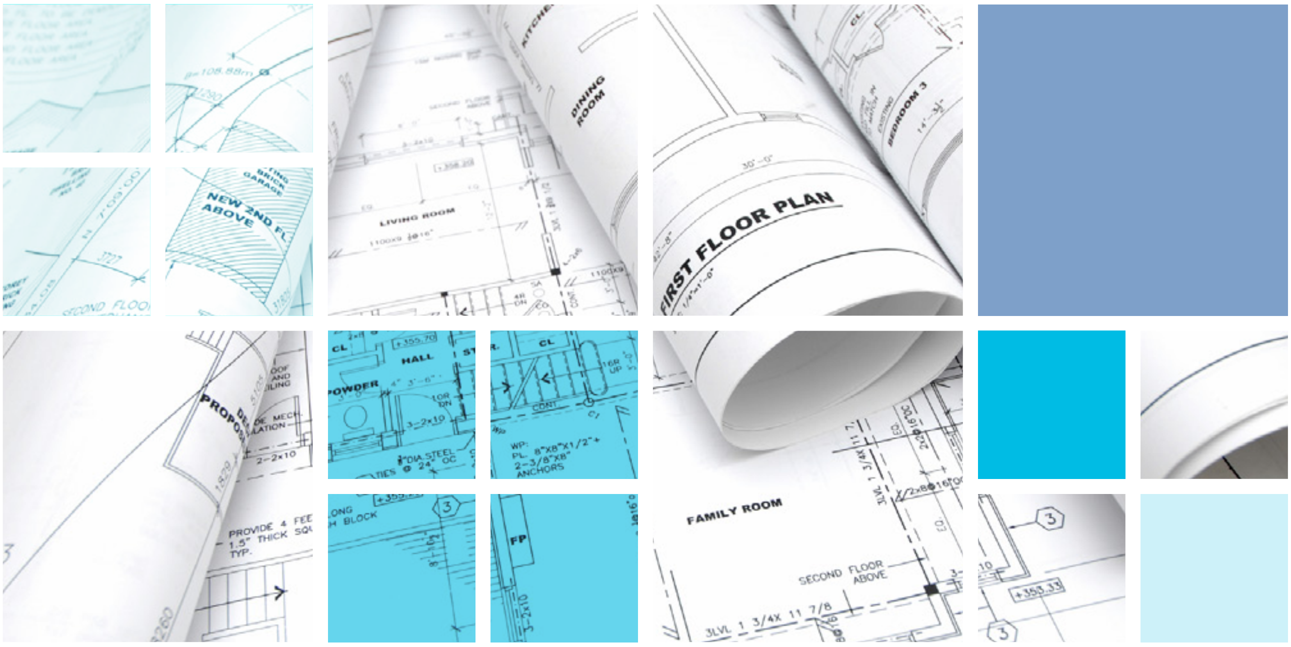
Figure 2 Energy use in a semi-detached zero carbon home

Note: At the time of writing the Government has not yet published the final definition of carbon compliance, however, it is understood that Zero Carbon Hub recommendations[7] will form the basis for future consultations on changes to the Building Regulations[8]. For the latest information on carbon compliance and allowable solutions please visit www.zerocarbonhub.org.

When considered in conjunction with the expected levels of base energy efficiency (ie the FEES) it becomes clear that the main areas of CO_2 emissions in order of magnitude relate to:

- appliances (49%)
- space heating (22%)
- water heating (11%)
- pumps and fans (10%)
- lighting (8%).

2 Description of the project



2.1 Process of investigation

The process of investigation is shown in Figure 3. The nature of this project required the creation of a team to review the technology and performance data resulting from industry discussions. Having identified a selection of technologies that appeared to have potential to become significant in the context of a 2016 home, the team used an assessment matrix to consider their relative potentials for success. This included technical, financial, policy and cultural issues. Following this, a shortlist of those considered to have the highest potential was taken forward by the BRE SAP team, who developed initial trial methodologies to allow an estimation of the possible CO_2 savings.

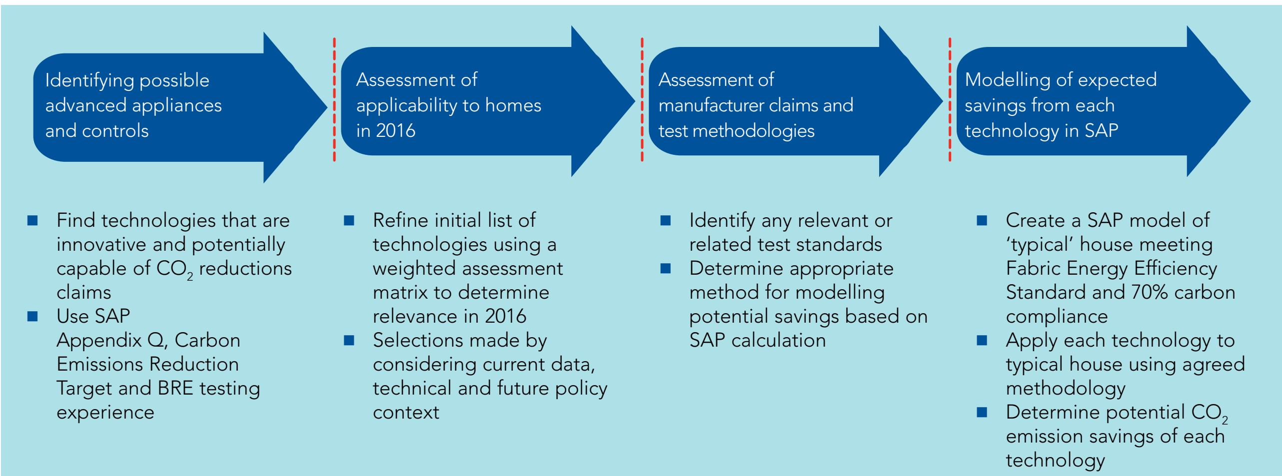


Figure 3 The process of investigation

It was agreed from the outset that the scope for the appliances and building control systems would be limited to fixed appliances (eg ventilation units, room heaters) and not include consumer items such as white or brown goods (eg refrigerators, TVs).

2.2 Scope of technologies

Figure 4 was developed to illustrate the potential areas that might be considered during discussions with industry. Note that although two of the control technologies have influence over appliance energy consumption, appliances themselves (along with smart building fabric) are excluded from the scope of this study (shown in the grey and green boxes).

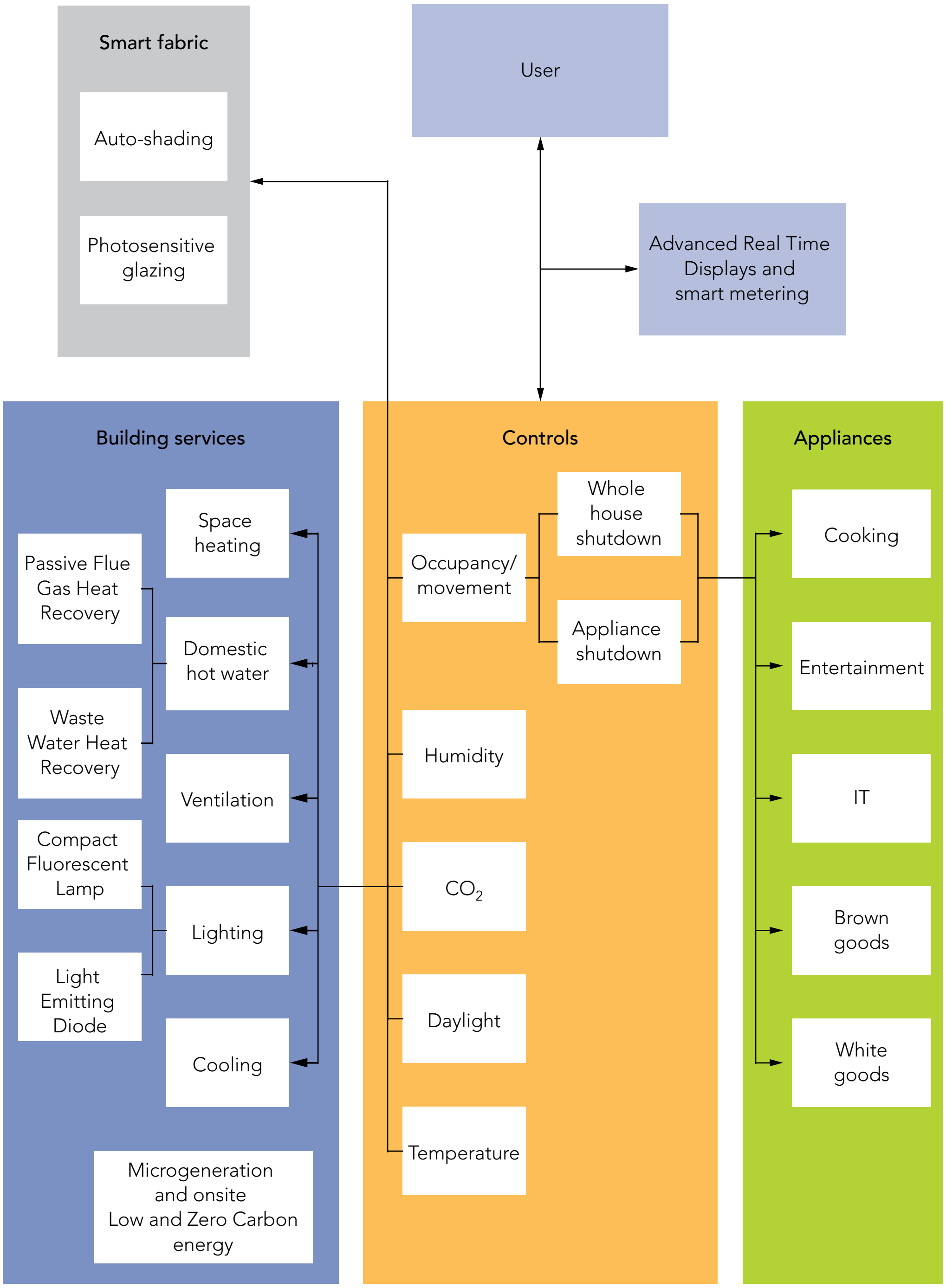


Figure 4 Domestic energy uses and potential control factors

2.3 Assessment matrix development

An assessment matrix was developed in order to ensure that the shortlisting of technologies from the initial range identified after discussions with industry was robust and transparent. This involved identifying a range of key issues from technical to policy, which the success of an energy efficient fixed appliance or building control system would be assessed against. Some of the issues identified were related to the ability of the technology in question to save energy and reduce CO_2 emissions from a home and some were wider issues that may affect the take-up of a new technology by industry, eg the availability of British Standard or European Standard test results. The issues identified and used for assessment were:

- Heat loss: potential for reducing space and water heating demand.
- Ability of the technology to reduce the electricity load of: appliances, pumps and fans, and lighting.
- Evidence: are British Standard or European Standard test results available where applicable?
- Installation: issues surrounding the ease of installation, availability of skills required.
- In service: operational lifespan and maintenance requirements.
- Financial: cost of the technology and potential time costs of installation.
- Lifestyle: impact on the lifestyle of home buyers (and hence developer's inclination to adopt).
- Policy: impact on the technology of likely future policy developments.

2.3.1 Creating a rating scale

Each technology was scored against the issues on a scale, generally from 1 to 5, based on criteria that were relevant to it. For example, the scale against which maintenance equipment was assessed was 1 point for a technology requiring monthly attention and 5 for a technology that was considered 'fit and forget'. The ability of a technology to reduce water heating load was assessed on a scale which awarded 1 point for a 2% saving and up to 5 points for a 20% saving.

2.3.2 Weighting the importance of the issues

Following the scoring of each technology against the issues, the scores were given a weighting factor from 1 to 10. The issues fell broadly into four categories: those that affect the dwelling owner or occupier, those that affect the developer, those that affect the building performance and those that are heavily influenced by policy. The weighting factors were independently assigned within these categories, ie a judgement was not made that issues in one category were more important than issues in another.

The first four issues, heat loss, appliance load, pump and fan energy, and lighting load, fell into the building performance category and were weighted relative to each other based on their respective contribution to dwelling CO_2 emissions as shown in Figure 2.

The remaining issues were assigned weighting factors based on how important each issue was to those who were most likely to be affected by it, either developers in the case of installation, for example, or home owners or occupiers in the case of lifestyle. Policy was highly weighted as it may have been the make or break factor for the applicability of an energy efficient fixed appliance or building control system. Note that the policy weighting reflects the pre-Budget policy position where unregulated energy was to be addressed via the allowable solutions aspect of the zero carbon new homes policy. For example, if smart meters with Real Time Displays (RTDs) were to become mandatory by 2016, their benefits were not considered as eligible for inclusion in the savings that were attributed to an allowable solution.

The weighting process allowed all the issues to be considered while giving greater importance to those issues considered most critical in terms of technology uptake by the industry. The result was a single final relevance score for each technology.

The applicability of each specific issue was influenced by the development stage of the technology. The technology was categorised as either an academic/blue sky, prototype or a market-ready product. Therefore, three different routes through the assessment matrix were developed.

Appendix A presents the issues facing current or potential technologies to a building control systems and the rating scale used for each of them.

Appendix B contains rating and weighting calculation matrices for all technologies reviewed. The assessment criteria have been greyed out if they are not applicable to a particular stage of the product life cycle.

Appendix C contains SAP 2009 modelling assumptions.

3 Industry scoping exercise

3.1 Discussions with industry

A project summary was created explaining the scope of research and aims. This was then circulated to a number of groups including the British Electrotechnical and Allied Manufacturers' Association (BEAMA), the Modern Built Environment Knowledge Transfer Network and the Energy Efficiency Partnership for Homes. Feedback was received from a variety of companies and members providing a valuable cross-section of opinions and possible technologies. Discussions were also held with those who worked with the Carbon Emissions Reduction Target (CERT), Energy Saving Trust (EST) and the Department of Environment and Climate Change (DECC) in order to identify any key policy issues.

The following technologies were identified during the industry discussions:

- demand control ventilation
- whole house shutdown
- next-generation Light Emitting Diode lighting
- shower Waste Water Heat Recovery
- Passive Flue Gas Heat Recovery
- solar-assisted Positive Input Ventilation
- advanced heating circulation pumps
- individual socket shutdown units
- smart meters and advanced Real Time Displays
- electric space heating controls
- bio-fuel secondary heating
- reduced storage temperature of domestic hot water.

These technologies are by no means the only ones in development but they do provide a snapshot of the technologies most likely to be brought to market in the short term. They are discussed in the following sub-sections and provide an overview of the key learning points from this phase.

3.1.1 Demand control ventilation

Following the successful launch of SAP Appendix Q for Mechanical Extract Ventilation (MEV) and balanced MVHR (Figure 5), the UK ventilation industry has seen significant increases in both fan and heat exchanger efficiency. There is now considerable interest from manufacturers to gain credit for advanced controls, beyond simple boost, on and off.

Innovations have been led mainly by the Dutch and Scandinavian markets. Systems are already available with sensors for movement, CO_2 and Relative Humidity (RH) levels. Data received from Itho Ventilation Ltd claims that its system, which uses CO_2 and RH sensors in conjunction with centralised extract, can reduce emissions in a Dutch model from 2686 kg/CO_2/year to 2081 kg/CO_2/year (circa 22% saving).

If a similar control system were to be included in SAP, there are some important issues that need to be addressed due to the intrinsic link between the Energy Efficiency (Part L) and Ventilation (Part F) elements of the Building Regulations:

- What occupancy profile should be used within the model to represent the production of moisture and CO_2?
- What reduced flow rate would be considered acceptable via Approved Document Part F, particularly in dwellings with an airtightness of less than 5 $m^3/h/m^2$ at 50 Pa?

One industry body has approached BRE with a proposed occupancy profile linked to more simple 'absent controls', where the unit only reduces its flow rate when the home is empty. Their estimation is that this could reduce energy consumption in an MEV system by 14% to 20%.

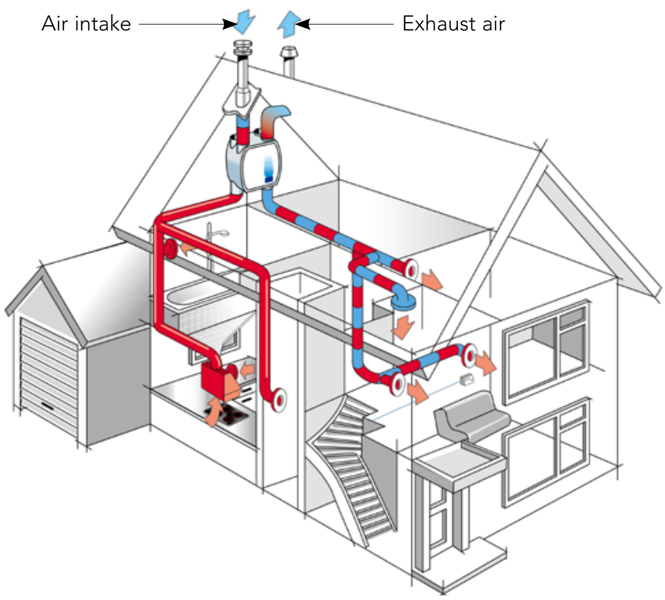


Figure 5 A Mechanical Heat Recovery and Ventilation system (image courtesy of Itho Ventilation Ltd)

It should also be mentioned that some industry representatives expressed concern that the inclusion of such reduced flow rates could be detrimental to indoor air quality because of a build-up of indoor air pollutants. Research conducted by the EST as part of the SAP Appendix Q programme revealed examples of poor installation and commissioning practice.

Some manufacturers feel that until this issue is resolved ventilation systems should not be fine-tuned to reduce flow rate as they may not be performing as originally intended. To resolve this situation The Electric Heating & Ventilation Association (TEHVA) is leading the development of a 'benchmark' scheme to improve installation quality and has played an active part in creating the installation guide for Approved Document Part F 2010.

Example products currently available can be found at www.itho.co.uk/Products/DemandFlow/Default.aspx?id=5315.

3.1.2 Whole house shutdown

These products take the concept of selected appliance shutdown to a whole house level (Figure 6). By using sophisticated switching controls and possibly an internet-based interface the central unit can be instructed to activate appliances, lights and possibly heating systems, remotely. Of most significance in CO_2 terms is the addition of radio-frequency transmitter key fobs carried by dwelling residents that enable the home to detect if anyone is in the property, and if not to shut down all but the pre-defined core systems.

In a similar manner to the individual shutdown units, these products are currently targeted at the existing stock, but their design and security features mean they could most likely transfer to the 'installed' new build market. This is only likely if there is sufficient demand to justify the more onerous product approval process.

Similar to demand control ventilation, the issue of key interest (if such a control system was to be included in SAP) is what occupancy profile should be used to represent a typical household and what percentage of appliances are technically suitable for shutting down in this manner? For example, hard drives, set top boxes and printers that park ink cartridges may not be able to operate correctly in this scenario.

Example products currently available include Greenswitch (www.greenswitchteam.com) and Alertme (www.alertme.com).

Figure 6 Example of a whole house shutdown system, showing a main control unit and plug-in appliance shutdown units. These may be integrated into the sockets themselves, or as circuits in new build applications

3.1.3 Next-generation Light Emitting Diode lighting

Light Emitting Diode (LED) lighting (Figure 7) is the main competitor for the more common Compact Fluorescent Lamps (CFLs), and is subject to considerable innovation. Research from the CALiPER programme into solid state lighting in the USA[9] suggests that there may be some concern regarding manufacturer claims of efficiency for products currently on the market. In addition, the US Department of Environment publishes projections for development over the coming years which are referenced by most in the industry[10]. These currently range from 62 lumens per circuit watt (lm/W) (2008) to 151 lm/W (2015) for commercial cool white light.

When quoting LED lighting efficacies it is important to distinguish between chip and luminaire efficacy. Chip efficacy is currently around 100 to 120 lm/W but luminaire efficacy is only 55% to 60% of these figures, which would suggest that the market leaders should reach 60 to 70 lm/W. Chip efficiency is the ratio of light the LED chip generates compared to the electrical input, whereas luminaire efficiency considers how much light the entire fitting generates from a given electrical input. Luminaire efficiency thus includes the efficiency of the electronic circuit driving the LED and fitting design.

There is a trade-off between colour temperature and rendering, and efficacy. The highest efficacy units are currently cool white (bluish) and with moderate colour rendering (a colour rendering index of 70 is acceptable for street lights but not in a domestic environment).

The Department for Environment, Food and Rural Affairs (DEFRA) is currently exploring the idea of energy class 'A' becoming mandatory from 2020 for all lighting (under revisions to the Energy Using Products Directive (EuP)[11]). This would allow CFLs to remain as well as LED lighting, but would eliminate halogen bulbs.

Example products currently available include Axent (www.artandsciencecombined.com) and PhotonStar – (www.photonstarlighting.co.uk).

Figure 7 Light Emitting Diode lamp

3.1.4 Shower Waste Water Heat Recovery

As dwelling fabric improves, water heating is responsible for an increasing proportion of total household CO_2 emissions. If fabric performance is significantly enhanced beyond the FEES, eg to Passivhaus levels of fabric performance, hot water generation is likely to be the second most significant source of CO_2 emissions in a 2016 dwelling after that resulting from electricity use.

Shower Waste Water Heat Recovery (WWHR) systems reduce the energy required to heat domestic hot water. The heat energy content of the waste water from showers (and other uses of hot water) is recovered as it is discharged through the soil stack and used to pre-heat the cold water supply to the shower and hot water cylinder or combination boiler.

One possible implementation of the technology (Figure 8) has a cold water pipe coiled around a central section of copper drainpipe. The potential loss of pressure in the potable water supply in this scenario can be overcome by wrapping several parallel pipes around the central drainpipe. Heat transfer from the central drainpipe to potable water is maximised by using a square cross-section pipe to form the coils, and relies on the falling film phenomena, whereby the waste water clings to the outer edges of the soil pipe. An example of this type of system is the PowerPipe from RenewABILITY Energy Inc. The PowerPipe system is undergoing SAP Appendix Q testing at the time of writing.

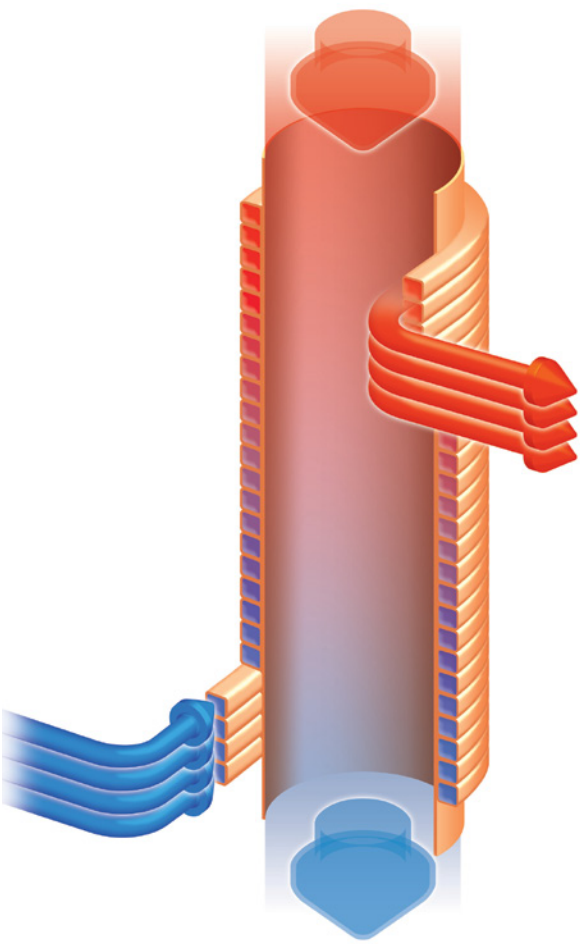


Figure 8 Cut-away diagram of the PowerPipe, courtesy of RenewABILITY Energy Inc

An alternative variant, the heat exchanger, takes the form of two concentric copper pipes with waste water flowing through the central pipe, clinging to the outside, and potable water for pre-heating flowing upwards in the narrow gap between the inner and outer pipe. An example of such a system is the Rehco-vert system currently eligible for inclusion in SAP calculations via SAP Appendix Q.

Where a vertical section of drainpipe is not present, heat exchangers that fit beneath the shower tray are also available such as Rehco-tray; however, these versions have a lower heat recovery efficiency than their vertical counterparts and may need periodic cleaning.

Recovery of heat from shower waste water has the potential to save around 40% of the energy use to heat water based on modelling of the Rehco-vert system undertaken for SAP Appendix Q inclusion. The technology requires no change in occupant behaviour, and is passive requiring no scheduled maintenance of filters, motors or moving parts in the vertical configuration.

3.1.5 Passive Flue Gas Heat Recovery

Passive Flue Gas Heat Recovery (PFGHR) systems have been developed by a number of boiler manufacturers. The systems recover the latent heat in the flue gases of condensing boilers to pre-warm the incoming cold water feed to the domestic hot water system. This improves the efficiency of the generation of hot water by combination boilers. It may also be used to pre-heat the cold supply to hot water cylinders if hot water is drawn off while the boiler is running, or if the PFGHR device installed incorporates a small quantity of stored water.

The flow rate of combination boilers can also be improved slightly by this technology. Some manufacturers, such as Baxi, are currently developing products that incorporate PFGHR into their boilers, rather than as an additional 'bolt on' unit over an existing boiler.

PFGHR is a technology recognised by SAP Appendix Q, with products from Zenex, Ravenheat, Alpha Boilers and ATAG having been assessed and included in the SAP Appendix Q database.

3.1.6 Solar-assisted Positive Input Ventilation

Solar-assisted Positive Input Ventilation (PIV) uses a novel air-based solar panel mounted to the roof structure in a similar manner to the more familiar solar thermal water-based system. Air is pre-heated by the solar panel and fed into the incoming air stream of a PIV unit. The system's unusual approach means standard testing procedures have previously been adapted to establish performance characteristics. The system can also be used with MVHR.

Data has been made available that shows the results of a 12-month monitoring project considering 10 new build homes. The systems produced on average 2200 kWh/year when providing both air pre-heating and a proportion of water heating. For the purposes of this report the system has only been considered in its simpler air pre-heat form to allow indicative SAP modelling. Subsequently to the modelling work for this report being completed, this technology has been recognised by SAP Appendix Q.

The available roof area within the context of the 70% carbon compliant home needs to be considered. The home modeled already has 3 m^2 solar hot water and 11 m^2 PV to achieve the 70% reduction in TER.

Example products currently available include those from Nuaire (www.sunwarm.com/heatrecov.shtml).

3.1.7 Advanced heating circulation pumps

The current assumption within SAP for heating circulation pumps is based upon traditional technologies with a 65 W pump running for 2000 hours per year, resulting in a total consumption of 130 kWh/year. A number of manufacturers have developed more advanced, and in principle, energy efficient pumps, which are based on variable flow rates, allowing them to react to the pressure changes that occur when thermostatic radiator valves open and close.

Current standard pumps tend to fall within the D to E energy efficiency label rating for this technology. The advanced pumps are A rated and can be up to 60% more efficient than standard pumps. Although this improvement is impressive, it must be acknowledged that pumps and fans only represent around 10% of the CO_2 emissions in the 70% carbon compliant home. Therefore, the overall savings in CO_2 terms are likely to be rather limited.

Example products currently available include the Grundfos Alpha (http://net.grundfos.com).

3.1.8 Individual socket shutdown units

Individual socket shutdown units are currently available aimed at the existing stock via the DIY market rather than new build homes. Typically, plug-in devices that fit between the appliance and wall socket (in the manner of the familiar time switches which have been in use for many years) allow the unit to completely switch off the power supply to the appliance when it moves to standby mode. Units of this type have been assessed and approved for use within CERT schemes.

The more advanced units, such as the one detailed via the link below, have a central remote control that allows 'zones' of appliances to be created and switched at specific times. Although these are currently retrofit units, in principle they could be incorporated into new build sockets. However, discussions with some product developers in this area suggest the regulatory and testing requirements are significantly more onerous if seeking to enter the 'hard-wired' market.

One aspect of these products that needs to be considered is the longevity of their advantages. Many appliances currently available have standby energy consumption features that could be much improved, and there is pressure on manufacturers via the EuP Directive to achieve significant improvements by 2016. This may result in appliance shutdown units saving less energy as time goes on, or even being integrated within other appliances.

Example products currently available include Bye Bye Standby (www.byebyestandby.com).

3.1.9 Smart meters and advanced Real Time Displays

The Government announced details of its plans to increase usage of smart metering via a consultation which closed on 3 August 2009. Following this the Government published a response: *Towards a Smarter Future: Government Response to the Consultation on Electricity and Gas Smart Metering*[12]. This confirmed that the Government intends to:

- Roll out to circa 50 million smart electricity and gas meters by approximately the end of 2020, with expected CO_2 emissions reductions of 2.6 million tonnes per year by 2020.
- Make supply companies responsible for installing and maintaining the smart meters.
- Establish a single national communications provider for all meters across the UK.
- Specify a high level functional description so that more detailed technical specifications can be defined.
- Probably require that a stand-alone RTD will be provided in addition to the main smart meter to provide details of CO_2, energy and cost. In some cases the TV and internet may be used to provide information.

The RTD concept is illustrated by the OWL energy monitor shown in Figure 9, which like a number of similar products on the market, can display both instantaneous electric power demand and historic electrical energy use over various user selected time periods. If programmed with the cost per kWh and emission factor it can also inform the user of electricity cost and CO_2 emission data. The most important aspect to be considered in this project was to assess how 'advanced' any future RTD or smart meter must be to be considered sufficiently beyond normal practice to merit additional gain via calculations.

Figure 9 Example of a Real Time Display unit (image courtesy of OWL)

The most innovative whole house monitoring system discovered is currently at prototype stage. Figure 10 illustrates the concept involved. Owing to the human element involved in the savings potentially resulting from RTDs, it is difficult to establish their influence. A range of CO_2 reduction figures has been identified that spread from a conservative 3.5%[13] to 15%[14].

This prototype whole house monitoring system is claimed to:

- Be one step beyond current RTDs which link directly to TVs, and a so called 'energy channel'.
- Be targeted at existing housing stock due to the larger potential market.
- Use 'plug-in' units for ease of retrofit which emits a radio signal so that each appliance can be monitored.
- Be capable of incorporation into new build, subject to meeting applicable regulations.
- Have the future potential to incorporate intelligent chips that provide consumption-related messages or recommendations.

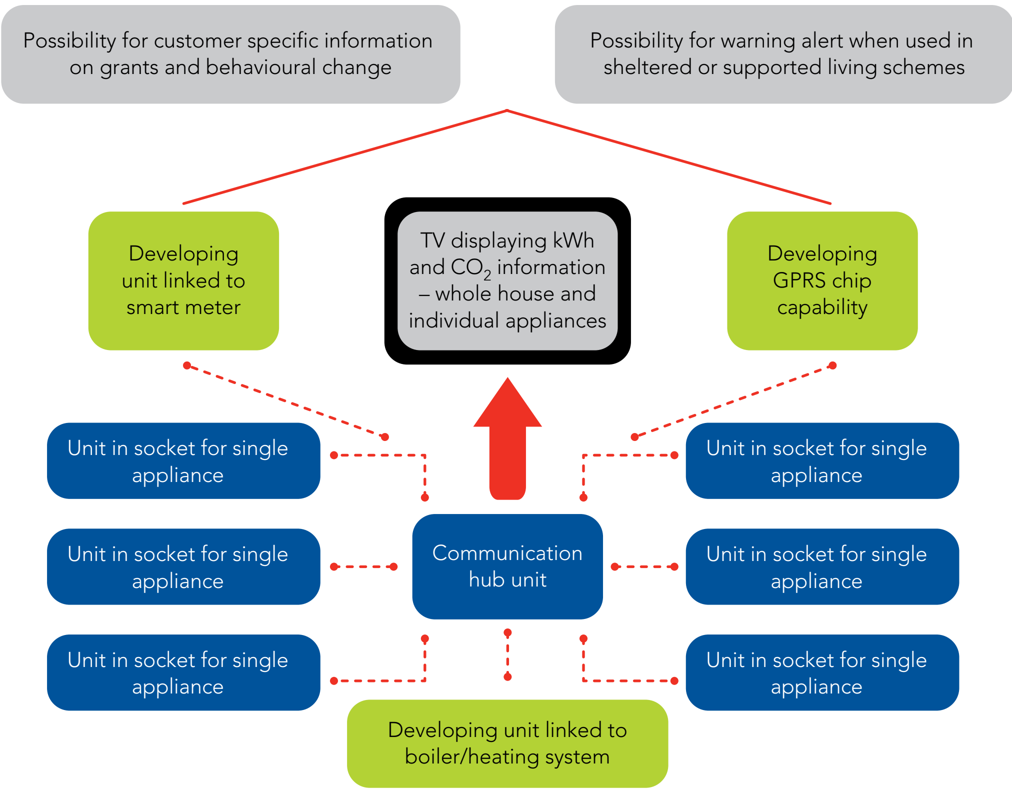


Figure 10 Innovative advanced Real Time Display system monitoring the whole house

3.1.10 Electric space heating controls

Several manufacturers were keen to raise their concerns regarding the current lack of research and development in their sector. The overriding opinion is that companies are currently struggling to retain market share due to the carbon intensity of grid-sourced electricity compared to that of gas as a heating fuel, the emphasis Part L places on dwelling emissions, and the growing planning requirements to comply with the Code for Sustainable Homes (CSH).

Research is continuing into advanced controls, mainly in France and Scandinavia, where there is a higher proportion of electric space heating installed than in the UK. Currently there is insufficient demand to justify importing any of these advanced control technologies to the UK market, as electric space heating in the UK is less common.

One example of an advanced electric space heating controller, shown in Figure 11, is made by Nobo. Nobo has developed a system using non-contact infrared temperature-sensing technology, coupled with integrated occupancy sensing. The resultant smart prototype systems are being field tested and monitored within (all-electric) student accommodation in Ireland. Preliminary results show the relative performance of two systems: one using standard thermostatic radiator panel controls and the other using a wireless sensor which incorporates the temperature and occupancy sensing to ensure optimum efficiencies. Monitoring ran from November 2008 to May 2009 and included three apartments with advanced panel heater control and 17 apartments with traditional thermostatic panel heater control. Results showed an 18% reduction in electricity readings (total electricity used in the apartment) for the more advanced control system. Monitoring is due to continue during the 2009 to 2010 season to examine the effect of different occupants (100 new occupants for the 20 apartments) on the potential savings of the control system. Additional trials in peoples' homes would confirm the wider applicability of these findings.

Figure 11 Nobo electric space heating controller

3.1.11 Bio-fuel secondary heating

SAP 2005[4] made an assumption that 10% of a dwelling's space heating would be provided by a secondary system, rather than by the main heating system used to heat a dwelling. In the absence of a secondary system being specified, eg a gas fire in the living room, SAP 2005 assumed that secondary heating would be provided by direct-acting electric heaters.

This assumption provided the opportunity to specify secondary heating using an energy source with a low CO_2 emission factor in order to improve the performance of a dwelling. For example, specifying a glass fronted gas fire would result in the secondary heating being provided using the SAP gas emission factor rather than that for electricity. Assuming the gas fire was sufficiently efficient this would improve the dwelling performance. The availability of secondary heating appliances using very low emission fuel, such as bio-ethanol gave rise to the possibility of savings in this area.

Subsequent versions of SAP introduced during the production of this report no longer assume that 10% of the space heating requirement is met from a secondary heating source; therefore, no further investigation has been made into the potential savings offered as this technology would not contribute to emission reductions within the current regulatory framework.

3.1.12 Reduced storage temperature of domestic hot water

Domestic hot water demand will become an increasingly major source of CO_2 emissions in the context of a 2016 dwelling. During research it became apparent that major innovations being considered within this area were based upon a reduction in water storage temperature from the current typical 60°C to around 50°C. This has the potential to increase heat pump efficiency and reduce heat loss from any storage vessel.

Many potential solutions based on reduced hot water storage temperature involve periodic sterilisation of the storage vessel by heating it to a temperature sufficiently high to kill legionella bacteria. However, there are concerns from a health and safety perspective about a reduction in water storage temperatures due to the potential for increased risks from legionella.

At the time of writing there was no clear guidance from the water regulations which led the research team to omit this approach from possible technologies. This also means that no specific approach was made by industry in the form of prototypes or market-ready products for consideration. Further research is needed to address this current lack of knowledge within an area of potential importance.

4 Selected technologies

This section provides details of the likely relevance in 2016, policy context and potential CO_2 savings for each of the shortlisted technologies. Full details of the assessment and matrix results can be found in Appendix A. Appendix B contains the assessments completed for each technology covered in the study and Appendix C contains the SAP 2009 modelling assumptions. The indicated potential CO_2 savings for each technology are only intended for the purpose of this research and are not applicable to any other SAP assessment, Part L calculation or CSH calculation.

4.1 Shortlist of selected technologies

The technologies reviewed in this report have been assessed both in terms of their likely potential in 2016 and their ability to reduce the CO_2 emissions of a dwelling in which they have been installed.

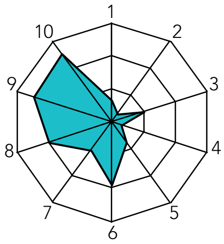
A shortlist of the technologies was drawn up in order of their potential:

- Technology 1 Demand control ventilation
- Technology 2 Whole house shutdown
- Technology 3 Next-generation Light Emitting Diode lighting
- Technology 4 Shower Waste Water Heat Recovery
- Technology 5 Passive Flue Gas Heat Recovery
- Technology 6 Solar-assisted Positive Input Ventilation
- Technology 7 Efficient heating circulators
- Technology 8 Individual socket shutdown units
- Technology 9 Advanced Real Time Displays.

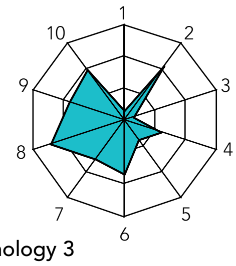
4.2 Potential relevance of selected technologies in 2016

The potential relevance of these technologies is illustrated in Figure 12. In general the greater the shaded area on the radar chart, the greater potential a technology is likely to have, as assessed using the method described in Section 2.3. The score of each technology gained in the assessment categories is plotted on the radial spokes of each chart and given as a percentage.

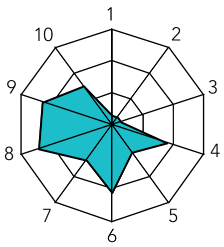
Technology 1
Demand control ventilation (61%)



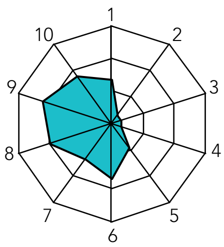
Technology 2
Whole house shutdown (60%)



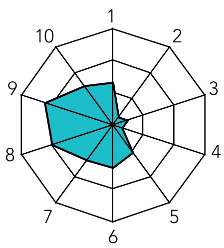
Technology 3
Next-generation Light Emitting Diode lighting (60%)



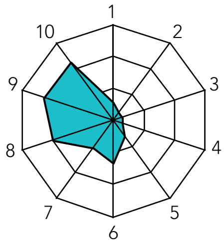
Technology 4
Shower Waste Water Heat Recovery (59%)



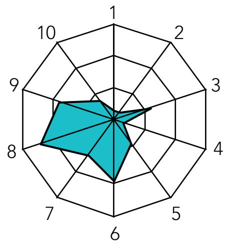
Technology 5
Passive Flue Gas Heat Recovery (55%)



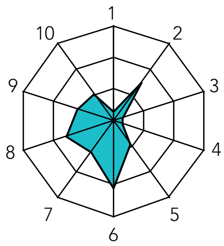
Technology 6
Solar-assisted Positive Input Ventilation (50%)



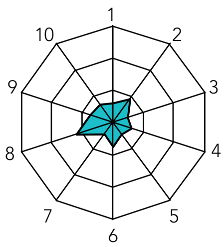
Technology 7
Efficient heating circulators (47%)



Technology 8
Individual socket shutdown units (43%)



Technology 9
Advanced Real Time Displays (30%)



Assessment categories

1	Heat loss	6	Installation
2	Appliances	7	Service
3	Pumps and fans	8	Financial
4	Lighting	9	Lifestyle
5	Evidence	10	Policy

Figure 12 Relevance of selected technologies in 2016

4.3 Potential for CO_2 emission reductions

The ability of each of the technologies to reduce the CO_2 emissions from a dwelling is shown in Figure 13. The rows, representing modelled dwelling emissions from a house with emission reductions of 70% compared to those stated in AD L1A 2006, are broken down into appliances, space heating, water heating, pumps and fans, and lighting categories as previously shown in Figure 4, thus demonstrating the category in which each technology provides a CO_2 emission reduction. The greatest reductions are provided by those technologies that target the electricity used to run household appliances, whole house shutdown and individual socket shutdown units, due to the carbon intensity of electricity compared to gas. The technology offering the greatest saving, regarding improvement to the building services, is shower WWHR. This technology has the advantage of reducing a significant energy load (water heating) regardless of how far the building fabric is improved.

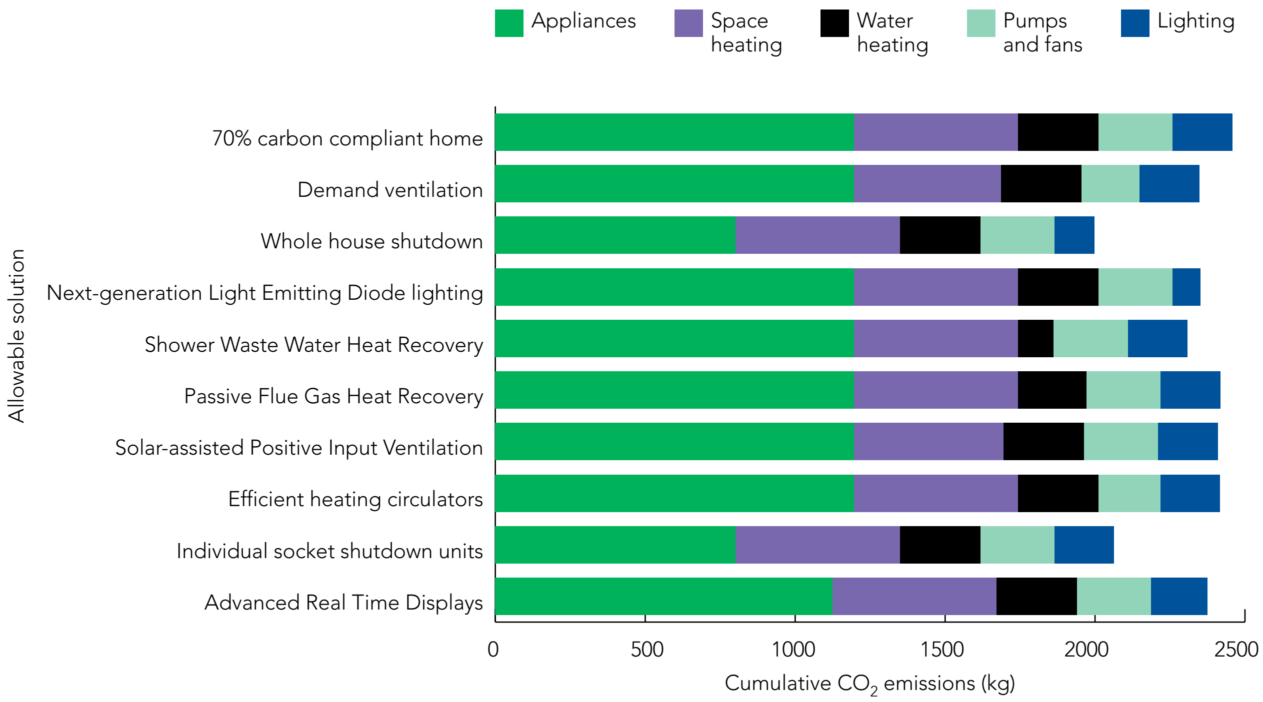


Figure 13 Overall emissions by use from typical dwelling incorporating potential allowable solutions

4.4 Discussion of technologies

4.4.1 Technology 1 Demand control ventilation

Demand control ventilation has evolved from MEV and MVHR systems that use CO_2 or RH sensors to determine occupancy and respond accordingly to deliver sufficient indoor air quality. To date they are used more in schools and commercial buildings to improve productivity. Flow rates are adjusted to meet pre-defined indoor air quality parameters.

Key features (Figures 14 and 15)

- Assumes a Mechanical Ventilation and Heat Recovery system as specified in all other scenarios operating at very low level (0.05 air changes per hour) for 12 hours per day instead of the SAP default of 0.5 air changes per hour. These hours of operation are based on the standard heating pattern assumed by SAP.
- Sensors placed within rooms can also open or close vents. The advanced control package is linked to Mechanical Extract Ventilation or Mechanical Ventilation and Heat Recovery fan speeds.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Demand control ventilation scenario emits 2348 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 110 kg/year (4.5%).

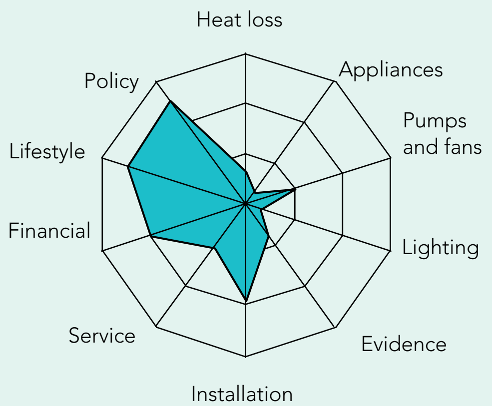


Figure 14 Demand control ventilation. Potential for significance in 2016 = 61%

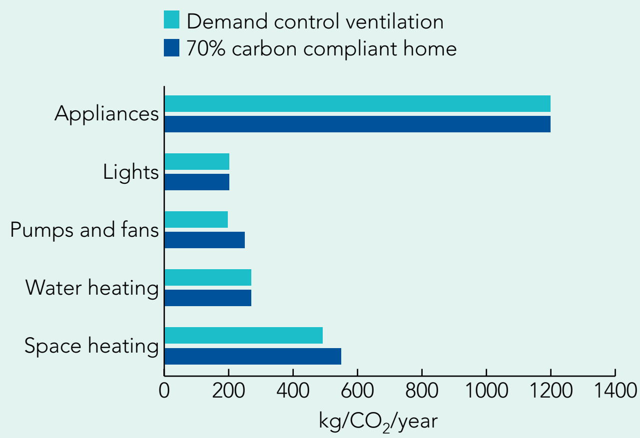


Figure 15 Potential impact of demand control ventilation

Opportunities

- Ability to improve indoor air quality.
- Ability to reduce both space heating and fan-related CO_2 emissions.
- Controls will be included in the ventilation system package so minimal additional installation required.
- It may be possible to adapt the technology for use with passive ventilation systems by developing vents that can be both humidity and time controlled. Unlike passive humidity controlled vents this would require an electronic control system. To prevent poor indoor air quality, however, humidity control should take precedence over timed closing of passive vents.

Barriers

- Concern that this level of fine tuning may increase the risk of under ventilation.
- Currently no clear guidance available on what is an acceptable setback rate during non-occupied periods.
- Developer may wish to pursue a natural ventilation strategy even in energy-efficient dwellings. This may preclude the use of the demand control system turning off or setting back a fan-driven ventilation unit.
- Industry concerns that current Mechanical Ventilation and Heat Recovery systems are underperforming due to poor installation (note installation is scored moderately well because it is the additional installation required for the control system that is being assessed here).

4.4.2 Technology 2 Whole house shutdown

As with the simpler individual socket shutdown units this is predominately a retrofit product at present. A key-fob-based control unit allows the system to know when the house is empty. Some systems have the ability to also report consumption and emissions to occupants.

Key features (Figures 16 and 17)

- Targets appliance standby and lighting consumption.
- Can be linked to internet-based controls.
- Key-fob triggering system automatically activates when house is empty.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Whole house shutdown scenario emits 1997 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 461 kg/year (19%).

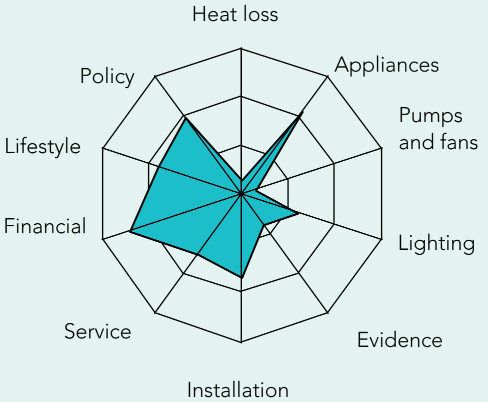


Figure 16 Whole house shutdown.
Potential for significance in 2016 = 60%

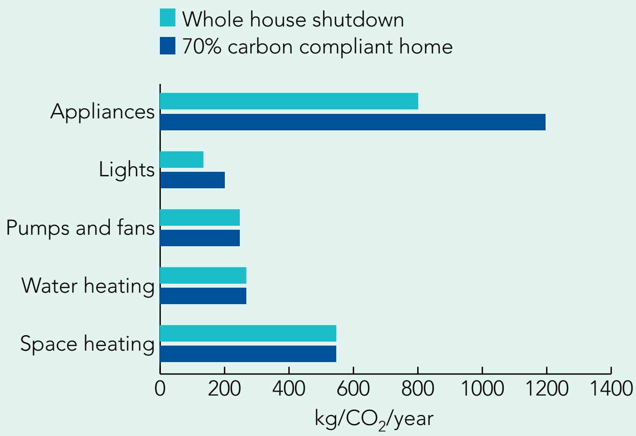


Figure 17 Potential impact of whole house shutdown

Opportunities

- Intelligent key-fob triggering system removes the occupant's need to control the system.
- More sophisticated systems can reduce lighting loads.
- Potential to be linked to heating and ventilation systems creating an intelligent building.
- Some systems could link to smart meters which then report to the occupant directly.

Barriers

- Retrofit market product may need to be incorporated into sockets for new build.
- EuP Directive activity improvements mean appliance standby power and lighting consumption is likely to drop considerably by 2016.
- No independent CO_2 savings available to date. Many appliances with hard drives etc may not be suitable for whole house shutdown thus a reduction in potential savings.
- Requires a simple interface to ensure user interaction is optimised.

4.4.3 Technology 3 Next-generation Light Emitting Diode lighting

Advances in materials, circuitry and controls are allowing LEDs to increase their luminaire efficiency and colour rendering performance. A range of potential future efficiencies are claimed from 65 lm/W (current best practice) to a US projection of 115 lm/W by 2015.

Key features (Figures 18 and 19)

- Considerably more efficient than current low energy lights (45 lm/W).
- Reduced heat generation and risk of overheating in more thermally efficient homes.
- Ability in the future to achieve higher efficiencies and retain acceptable colour rendering.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Next-generation Light Emitting Diode lighting scenario emits 2351 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 107 kg/year (4.4%).

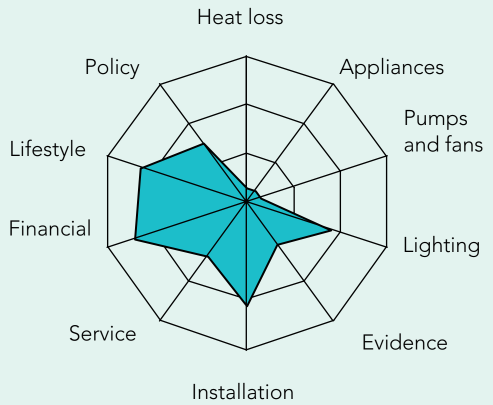


Figure 18 Next-generation Light Emitting Diode lighting. Potential for significance in 2016 = 60%

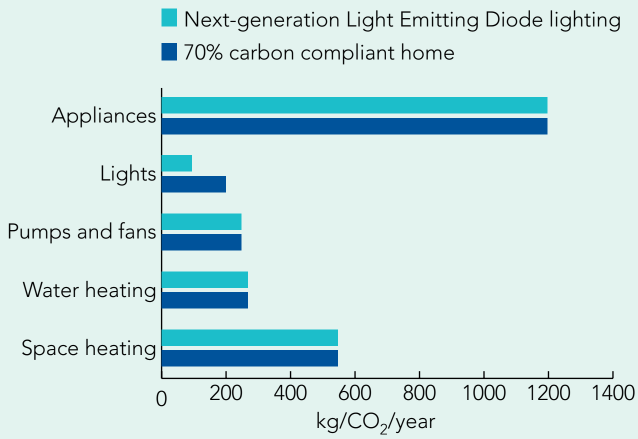


Figure 19 Potential impact of next-generation Light Emitting Diode lighting (65 lm/W)

Opportunities

- Simply substitute the product with considerably higher efficiency potential.
- Reduced heat generation will help avoid internal overheating.
- Low voltage circuit could take advantage of photovoltaic-generated direct current electricity without inverter losses.

Barriers

- Colour rendering quality has potential to cause consumer rejection if not prioritised.
- Some limited concerns identified regarding the health implications of the technology.
- Currently there is an industry debate over claimed performances for some products. Limited independent data is available.

4.4.4 Technology 4 Shower Waste Water Heat Recovery

Waste Water Heat Recovery (WWHR) systems are water to water heat exchangers. In their most common implementation they replace a section of the vertical soil pipe into which shower(s) discharge. Warm grey water falls down the soil pipe, clinging to its inner surface and warming the potable water feed to the water heater (combination boiler or cylinder) and/or shower, which is carried in a concentric pipe around the soil pipe, or in a coil of pipe wrapped around the soil pipe. They save a portion of the energy required to heat the hot water used by showers.

Key features (Figures 20 and 21)

- Targets energy use for heating domestic hot water – the most significant area of energy use aside from appliances.
- Does not require interaction from building occupants.
- Low maintenance.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Scenario with shower Waste Water Heat Recovery system emits 2308 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 150 kg/year (6.8%).

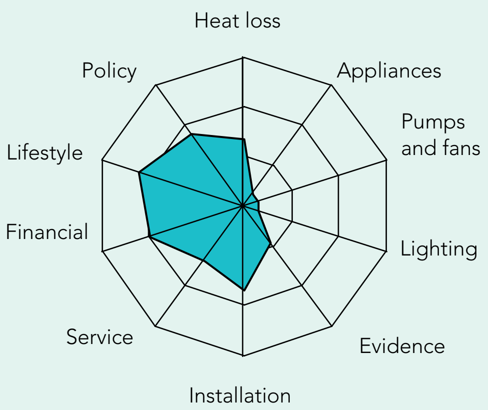


Figure 20 Shower Waste Water Heat Recovery. Potential for significance in 2016 = 59%

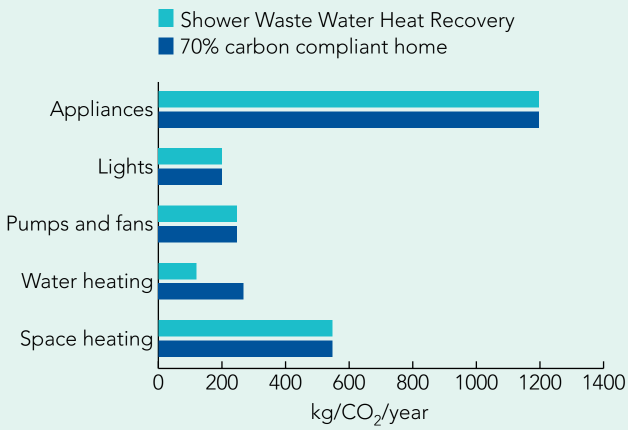


Figure 21 Potential impact of shower Waste Water Heat Recovery

Opportunities

- Heat recovered from waste water has potential to save around 44% of energy used to heat water.
- Saving energy used for water heating removes the pressure on developers to optimise building fabric.
- In most implementations it is a 'fit and forget' technology requiring no user interaction or maintenance.

Barriers

- In its standard form it requires around 2 m of vertical waste water pipe below the shower to which it is fitted; this would be difficult on the ground floor or in flats.

4.4.5 Technology 5 Passive Flue Gas Heat Recovery

An additional heat exchanger is placed in the boiler flue, warm exhaust gases from the boiler pass though the heat exchanger which pre-warms the flow of cold water into the combination boiler or hot water cylinder. In some cases the flue gases are used to pre-heat a small pressurised vessel of stored water which is then used as the supply to the combination boiler. While PFGHR may be used with both combination and cylinder-based hot water systems, it provides greater benefit when used in conjunction with a combination boiler, to gain maximum benefit from the system, simultaneous operation of the boiler and hot water consumption is required. For the purposes of this report, however, the standard house configuration used for SAP modelling incorporated a hot water cylinder and this was used in assessing all technologies including PFGHR.

Key features (Figures 22 and 23)

- Targets combination boiler efficiency in domestic hot water mode.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Does not require interaction from building occupants.
- Scenario with Passive Flue Gas Heat Recovery system emits 2417 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 40 kg/year (1.7%).

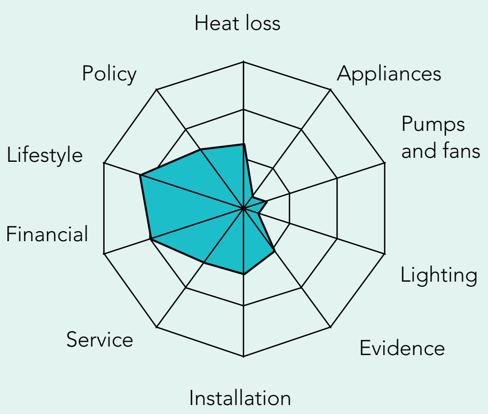


Figure 22 Passive Flue Gas Heat Recovery. Potential for significance in 2016 = 55%

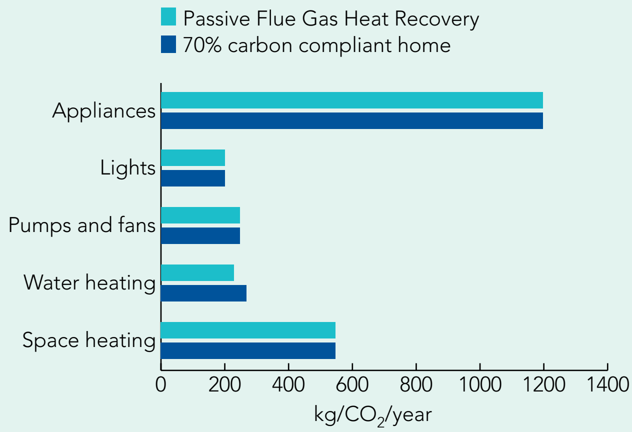


Figure 23 Potential impact of Passive Flue Gas Heat Recovery

Opportunities

- No additional skills required for installation over and above those already possessed by heating installers.
- Applicable to all new combination boiler installations.
- Potentially minimal capital cost if Passive Flue Gas Heat Recovery is eventually incorporated into boilers.

Barriers

- If incorporated into boilers as a standard feature before 2016, efficiency improvements will be delivered via a specified SEDBUK efficiency used at Part L.

4.4.6 Technology 6 Solar-assisted Positive Input Ventilation

An air-based solar panel system that raises the incoming air temperature above ambient and then links to either PIV or MVHR.

Key features (Figures 24 and 25)

- Uses a solar air panel on the roof space.
- Pre-heats air prior to entry into homes so it can theoretically work to assist the Mechanical Ventilation and Heat Recovery heat exchanger.
- Assuming the system can increase incoming air temperature by 5°C for half of the heating season.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Solar-assisted Positive Input Ventilation system scenario emits 2409 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 49 kg/year (2%).

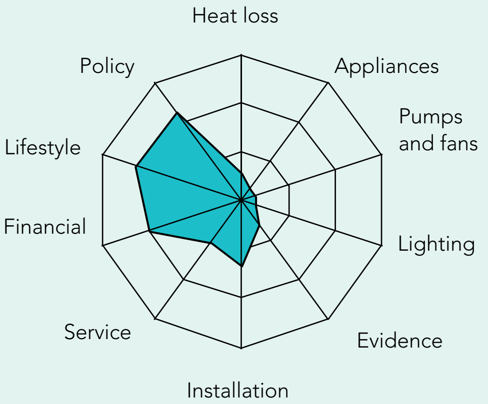


Figure 24 Solar-assisted Positive Input Ventilation. Potential for significance in 2016 = 50%

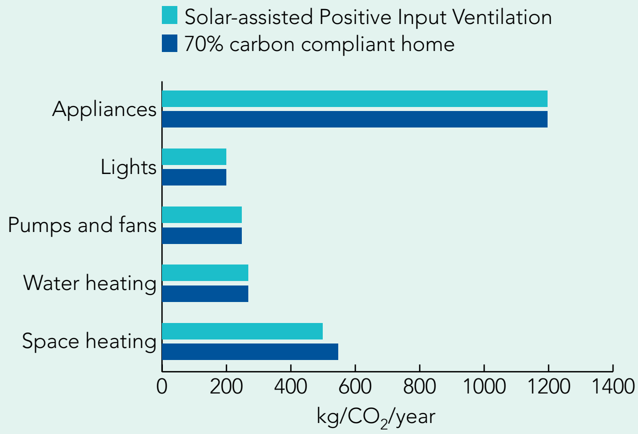


Figure 25 Potential impact of solar-assisted Positive Input Ventilation

Opportunities

- Comparatively simple addition to existing Mechanical Ventilation and Heat Recovery technologies likely to be seen in 2016.
- Potential to reduce the need for pre-heating in Mechanical Ventilation and Heat Recovery systems used for all space-heating provision.
- Independent monitoring has shown average energy generation of 980 kWh/year. (This calculation is based on a conservative assumption of 245 kWh/year and does not include the potential for water heating savings.)

Barriers

- Requires correctly oriented roof area that will already be under pressure from solar hot water and photovoltaics in a 70% carbon compliant home.

4.4.7 Technology 7 Efficient heating circulators

This technology uses central heating system circulation pumps that use more efficient, variable speed motors. There is a range of energy labelling standards available which are generally 'A' rated.

Key features (Figures 26 and 27)

- Variable speed pumps.
- More efficient motors and materials.
- Assuming 60% more efficient than a traditional pump.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Efficient heating circulator system scenario emits 2417 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 41 kg/year (1.7%).

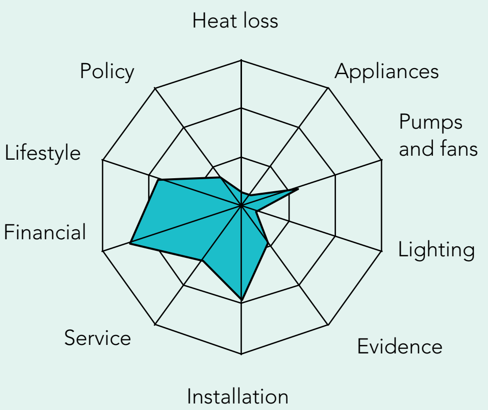


Figure 26 Efficient heating circulators.
Potential for significance in 2016 = 47%

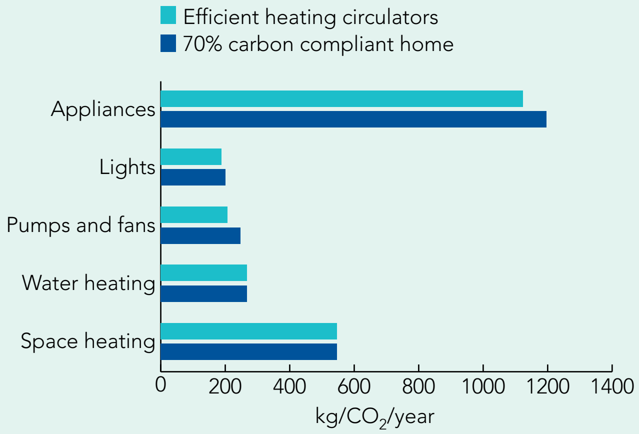


Figure 27 Potential impact of efficient heating circulators

Opportunities

- Products are already available and are included in Carbon Emissions Reduction Target schemes for refurbishment.
- Simple product substitution that could save up to 60% of pump energy consumption.

Barriers

- EuP Directive labelling requirements may mean the potential savings compared to normal practice will be reduced by 2016.
- Energy efficient homes are less likely to require traditional wet central heating so this may not be installed in great numbers.
- Pumps and fans only represent circa 9% of total CO_2 emissions. Heating is circa 28% of this total so limited overall impact.
- No independent CO_2 savings based on typical UK operating profiles available to date.

4.4.8 Technology 8 Individual socket shutdown units

Currently aimed at the retrofit market these units can be programmed to completely switch off electrical power to appliances left on standby. Units fit between plug and existing socket with a manual switch or remote control.

Key features (Figures 28 and 29)

- Targets appliance standby consumption.
- Remote control switching allows zones.
- Can control appliances up to 3 kW.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Scenario with individual socket shutdown units system emits 2063 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 395 kg/year (16%).

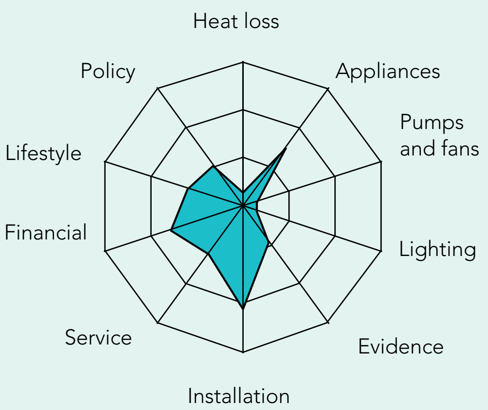


Figure 28 Individual socket shutdown units.
Potential for significance in 2016 = 43%

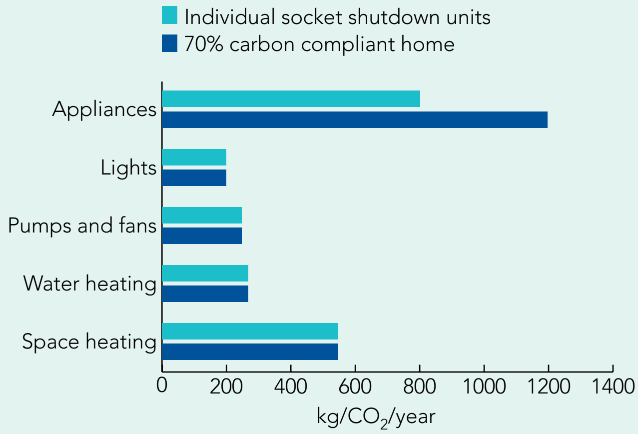


Figure 29 Potential impact of individual socket shutdown units

Opportunities

- Existing technology with proven functionality.
- Multiple zones so different appliance types can be controlled.
- Potentially low capital cost if incorporated into sockets during manufacture.

Barriers

- Retrofit market product would need to be incorporated into sockets for new build.
- EuP Directive activity for appliances means standby power is likely to drop considerably by 2016.
- No independent CO_2 savings available to date and highly sensitive to occupant activity.
- Does not report impact of actions to occupant.

4.4.9 Technology 9 Advanced Real Time Displays

This is a prototype system that innovatively links the satellite/cable TV home system with monitoring hardware for heat, lights and appliances. It is currently targeting the retrofit market as appliance testing standards for 'plug and play' units are less onerous than new build products.

Key features (Figures 30 and 31)

- Targets appliance standby, lighting and heating consumption.
- Link to home entertainment system to raise profile of emissions/costs.
- 70% carbon compliant home emits 2458 kg/CO_2/year.
- Scenario with advanced Real Time Displays system emits 2374 kg/CO_2/year.
- Has potential to reduce CO_2 emissions by 84 kg/year (3.6%).

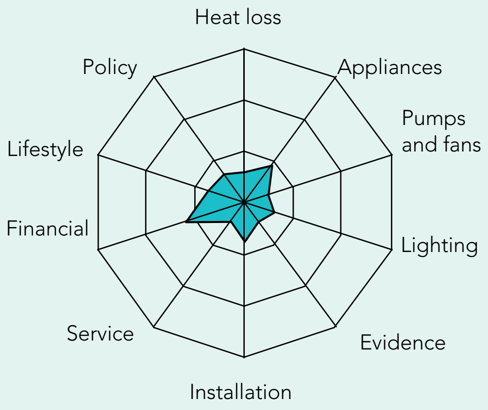


Figure 30 Advanced Real Time Displays. Potential for significance in 2016 = 30% (prototype)

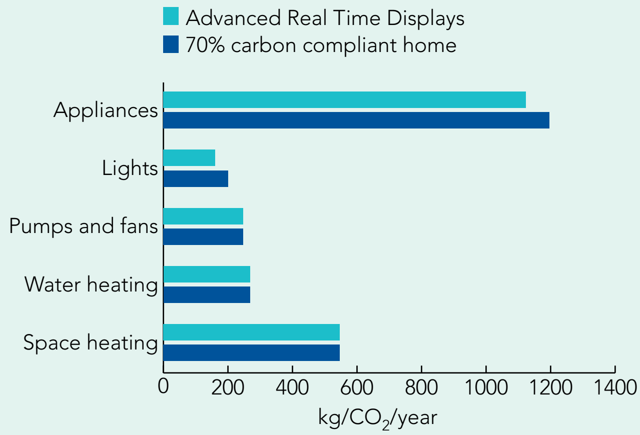


Figure 31 Potential impact of advanced Real Time Displays

Opportunities

- Links to power and heating systems increase potential savings.
- Innovative use of home entertainment system could increase occupant engagement.
- Two-way communication with energy supplier has potential for future smart grid applications.
- Prototype stage so ability to develop with focus on new build sector.

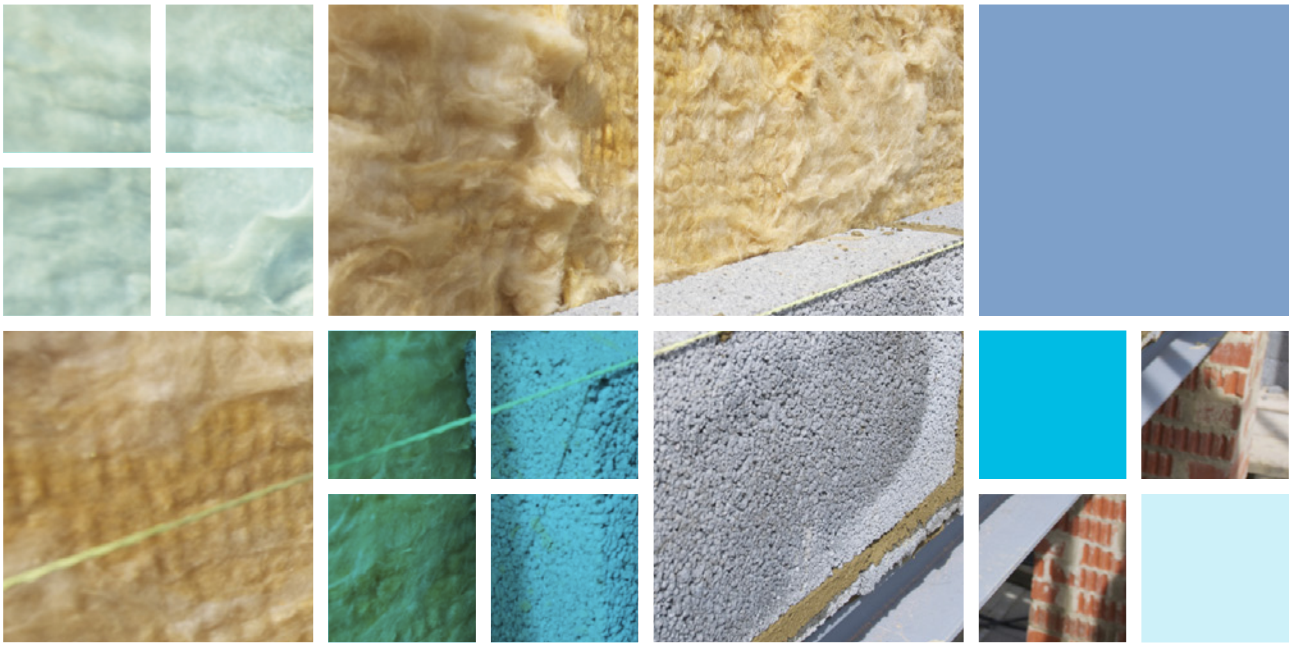
Barriers

- Currently only at prototype stage.
- Smart meter roll out by 2020 will mean relative savings potential compared to 'normal' systems will be reduced by 2016.
- Totally reliant on occupant engagement and initial savings may reduce over time.
- Feedback to supplier could bring 'Big Brother' resistance.
- No independent CO_2 savings available to date and highly sensitive to occupant activity.

4.5 Summary of findings

For the purposes of this report FEES was applied to the dwelling and then technologies such as MVHR, solar thermal and PV panels were added until a 70% reduction in the DER was achieved relative to the TER. When considered in conjunction with the expected level of base energy efficiency, ie FEES, it becomes clear that the main areas of CO_2 emissions in order of significance relate to appliances, space heating, water heating, pumps and fans and finally lighting. If advanced building fabric, such as that required to achieve the Passivhaus standard is employed, water heating becomes more significant than space heating. Appliances are the principal source of CO_2 emissions due to the emission factor currently associated with the electricity that powers them. Space and water heating is provided by gas, which is associated with a lower emission factor.

5 Conclusion



It has been demonstrated that of the five technologies assessed to have the greatest relevance in 2016, the two that stand out as offering the greatest CO_2 emission reductions are whole house shutdown (19% reduction) and WWHR (6.8% reduction).

Appliance and control manufacturers consider inclusion within SAP of primary importance when trying to market a product. Many developers are likely to be prepared to specify a more advanced (and potentially more expensive) item only where there is a demonstrable benefit within SAP calculations. It is therefore more attractive to manufacturers if their advanced products are eligible for inclusion within the carbon compliance calculations rather than as allowable solutions.

This viewpoint has generally been reflected within the research team in terms of regulatory process and continuity. Table 2 shows what is likely to be the most appropriate approach to including the benefits of each of the reviewed technologies when assessing the performance of dwellings.

Table 2 Applicable policy category for selected technologies

Technology	Energy efficiency or carbon compliance	Allowable solution (additional carbon saving)
1 Demand control ventilation	✓	
2 Whole house shutdown		✓
3 Next-generation Light Emitting Diode lighting	✓	
4 Shower Waste Water Heat Recovery	✓	
5 Passive Flue Gas Heat Recovery	✓	
6 Solar-assisted Positive Input Ventilation	✓	
7 Efficient heating circulators	✓	
8 Individual socket shutdown units		✓
9 Advanced Real Time Displays		✓

The majority of the technologies are best considered via the carbon compliance calculation tool. The three exceptions to this, which are considered more appropriate to allowable solutions (additional carbon savings) are:

- **Whole house shutdown:** targets appliance usage not included within the 'core SAP' calculation. This has the potential to distort the DER if savings are assigned to reduce other sources of CO_2 emissions.
- **Individual socket shutdown units:** again this targets appliance usage not included within the core SAP calculation; however, it has less scope for savings than whole house shutdown.
- **Advanced RTD:** reliant upon occupant behaviour, over indefinite periods of time. Due to the nature of human behaviour it would seem very difficult, and potentially unwise, to establish a single CO_2 saving figure without considerably more monitoring than is available to date.

Of these it appears likely the benefits of advanced RTD will be overtaken by the forthcoming smart meter roll out leaving the two other similar technologies that reduce the electricity consumption of unoccupied houses as the most beneficial additional carbon-saving measures.

Appendix A
Rating of issues facing potential energy efficient fixed appliances and building control systems

Appendix A contains copies of the assessments completed for each technology area considered within this report.

Heat loss	Rating scales
Ability to reduce space heating requirements	1 = <2% 2 = <5 3 = <10 4 = <15 5 = >20%
Ability to reduce domestic hot water requirements	1 = <2% 2 = <5 3 = <10 4 = <15 5 = >20%
Appliance load	**Rating scales**
Ability to reduce appliance electrical load	1 = <2% 2 = <5 3 = <10 4 = <15 5 = >20%
Pumps and fans load	**Rating scales**
Ability to reduce pumps and fans electrical load	1 = <2% 2 = <5 3 = <10 4 = <15 5 = >20%
Lighting load	**Rating scales**
Ability to reduce lighting electrical load	1 = <2% 2 = <5 3 = <10 4 = <15 5 = >20%
Evidence	**Rating scales**
Availability of suitable existing British or European testing Standards	0 = No 2 = Yes
Availability of test data	0 = No test data available 1 = Non-independent data 2 = Independent test data 3 = Full UKAS-accredited test data and certification
Installation	**Rating scales**
Ability to be installed with current industry skills	1 = Needs accredited team 5 = Basic DIY single person
Ability to be installed within current industry process	1 = Requires more than two additional trades 5 = Direct replacement or rationalises current steps

Service	Rating scales
Ability to operate without increased maintenance requirements	1 = Requires specialist six monthly visit 5 = Fit and forget
Operational lifespan	1 = Less than five years 5 = 60 years plus
Financial	**Rating scales**
Ability to be used at no additional capital cost	1 = Over 100% increase 5 = Less than 10% increase
Lifestyle	**Rating scales**
Ability to be used without occupant noticing any change from current situation	1 = Requires daily intervention 5 = No occupant input required
Ability to improve the indoor environment	1 = Possible increased noise/reduction in IAQ 5 = Reduced noise/constantly below 70% Relative Humidity
Policy	**Rating scales**
Likelihood of becoming mandatory feature before 2016	0 = Scheduled within current EU plans 5 = Unknown technology
Wider political sensitivities to this type of technology	1 = Radioactive components/genetically modified 5 = Organic fair trade

Appendix B
Assessment matrices

Appendix B contains copies of the assessments completed for each technology area considered within this report. The weightings are shown in red in the following tables to distinguish them from the scores assigned to each technology.

Technology 1 Demand control ventilation									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements	0	10	0	0	3	0	4	3	12
Ability to reduce domestic hot water requirements	0	10	0	0	7	0	0	7	0
Appliance load									
Ability to reduce appliance electrical load	0	10	0	0	10	0	0	10	0
Pumps and fans load									
Ability to reduce pumps and fans electrical load	0	10	0	0	3	0	4	3	12
Lighting load									
Ability to reduce lighting electrical load	0	10	0	0	5	0	0	5	0
Evidence									
Availability of suitable existing British or European testing Standards							2	5	10
Availability of test data				0	5	0	1	5	5
Installation									
Ability to be installed with current industry skills				0	5	0	4	7	28
Ability to be installed within current industry process							5	5	25
Service									
Ability to operate without increased maintenance requirements				0	1	0	3	5	15
Operational lifespan							2	5	10
Financial									
Ability to be used at no additional capital cost				0	5	0	4	7	28
Lifestyle									
Ability to be used without occupant noticing any change from current situation				0	5	0	4	10	40
Ability to improve the indoor environment	0	5	0	0	5	0	4	8	32
Policy									
Likelihood of becoming mandatory feature before 2016				0	10	0	5	10	50
Wider political sensitivities to this type of technology				0	1	0	5	5	25
Total rating	0.00		0.00	0.00		0.00	47.00		292.00
Success potential	0%		0%	0%		0%	63%		61%

Technology 2 Whole house shutdown									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements	0	10	0	0	3	0	0	3	0
Ability to reduce domestic hot water requirements	0	10	0	0	7	0	0	7	0
Appliance load									
Ability to reduce appliance electrical load	0	10	0	0	10	0	3	10	30
Pumps and fans load									
Ability to reduce pumps and fans electrical load	0	10	0	0	3	0	0	3	0
Lighting load									
Ability to reduce lighting electrical load	0	10	0	0	5	0	3	5	15
Evidence									
Availability of suitable existing British or European testing Standards							2	5	10
Availability of test data				0	5	0	1	5	5
Installation									
Ability to be installed with current industry skills				0	5	0	3	7	21
Ability to be installed within current industry process							5	5	25
Service									
Ability to operate without increased maintenance requirements				0	1	0	5	5	25
Operational lifespan							3	5	15
Financial									
Ability to be used at no additional capital cost				0	5	0	5	7	35
Lifestyle									
Ability to be used without occupant noticing any change from current situation				0	5	0	5	10	50
Ability to improve the indoor environment	0	5	0	0	5	0	0	8	0
Policy									
Likelihood of becoming mandatory feature before 2016				0	10	0	3	10	30
Wider political sensitivities to this type of technology				0	1	0	5	5	25
Total rating	0.00		0.00	0.00		0.00	43.00		286.00
Success potential	0%		0%	0%		0%	57%		60%

Technology 3 Next-generation Light Emitting Diode lighting									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements	0	10	0	0	3	0	0	3	0
Ability to reduce domestic hot water requirements	0	10	0	0	7	0	0	7	0
Appliance load									
Ability to reduce appliance electrical load	0	10	0	0	10	0	0	10	0
Pumps and fans load									
Ability to reduce pumps and fans electrical load	0	10	0	0	3	0	0	3	0
Lighting load									
Ability to reduce lighting electrical load	0	10	0	0	5	0	5	5	25
Evidence									
Availability of suitable existing British or European testing Standards							2	5	10
Availability of test data				0	5	0	3	5	15
Installation									
Ability to be installed with current industry skills				0	5	0	5	7	35
Ability to be installed within current industry process							5	5	25
Service									
Ability to operate without increased maintenance requirements				0	1	0	4	5	20
Operational lifespan							3	5	15
Financial									
Ability to be used at no additional capital cost				0	5	0	5	7	35
Lifestyle									
Ability to be used without occupant noticing any change from current situation				0	5	0	5	10	50
Ability to improve the indoor environment	0	5	0	0	5	0	2	8	16
Policy									
Likelihood of becoming mandatory feature before 2016				0	10	0	2	10	20
Wider political sensitivities to this type of technology				0	1	0	4	5	20
Total rating	0.00		0.00	0.00		0.00	45.00		286.00
Success potential	0%		0%	0%		0%	60%		60%

Technology 4 Shower Waste Water Heat Recovery									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements		10	0		3	0	0	3	0
Ability to reduce domestic hot water requirements		10	0		7	0	5	7	35
Appliance load									
Ability to reduce appliance electrical load		10	0		10	0	0	10	0
Pumps and fans load									
Ability to reduce pumps and fans electrical load		10	0		3	0		3	0
Lighting load									
Ability to reduce lighting electrical load		10	0		5	0	0	5	0
Evidence									
Availability of suitable existing British or European testing Standards							2	5	10
Availability of test data					5	0	2	5	10
Installation									
Ability to be installed with current industry skills					5	0	3	7	21
Ability to be installed within current industry process							5	5	25
Service									
Ability to operate without increased maintenance requirements					1	0	4	5	20
Operational lifespan							3	5	15
Financial									
Ability to be used at no additional capital cost					5	0	4	7	28
Lifestyle									
Ability to be used without occupant noticing any change from current situation					5	0	4	10	40
Ability to improve the indoor environment		5	0		5	0	3	8	24
Policy									
Likelihood of becoming mandatory feature before 2016					10	0	3	10	30
Wider political sensitivities to this type of technology					1	0	4	5	20
Total rating	0.00		0.00	0.00		0.00	42.00		278.00
Success potential	0%		0%	0%		0%	56%		59%

Technology 5 Passive Flue Gas Heat Recovery									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements		10	0		3	0	2	3	6
Ability to reduce domestic hot water requirements		10	0		7	0	4	7	28
Appliance load									
Ability to reduce appliance electrical load		10	0		10	0	0	10	0
Pumps and fans load									
Ability to reduce pumps and fans electrical load		10	0		3	0	1	3	3
Lighting load									
Ability to reduce lighting electrical load		10	0		5	0	0	5	0
Evidence									
Availability of suitable existing British or European testing Standards							2	5	10
Availability of test data					5	0	3	5	15
Installation									
Ability to be installed with current industry skills					5	0	2	7	14
Ability to be installed within current industry process							4	5	20
Service									
Ability to operate without increased maintenance requirements					1	0	5	5	25
Operational lifespan							2	5	10
Financial									
Ability to be used at no additional capital cost					5	0	4	7	28
Lifestyle									
Ability to be used without occupant noticing any change from current situation					5	0	4	10	40
Ability to improve the indoor environment		5	0		5	0	3	8	24
Policy									
Likelihood of becoming mandatory feature before 2016					10	0	2	10	20
Wider political sensitivities to this type of technology					1	0	4	5	20
Total rating	0.00		0.00	0.00		0.00	42.00		263.00
Success potential	0%		0%	0%		0%	56%		55%

Technology 6 Solar-assisted Positive Input Ventilation									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements	0	10	0	0	3	0	3	3	9
Ability to reduce domestic hot water requirements	0	10	0	0	7	0	0	7	0
Appliance load									
Ability to reduce appliance electrical load	0	10	0	0	10	0	0	10	0
Pumps and fans load									
Ability to reduce pumps and fans electrical load	0	10	0	0	3	0	0	3	0
Lighting load									
Ability to reduce lighting electrical load	0	10	0	0	5	0	0	5	0
Evidence									
Availability of suitable existing British or European testing Standards							0	5	0
Availability of test data				0	5	0	2	5	10
Installation									
Ability to be installed with current industry skills				0	5	0	2	7	14
Ability to be installed within current industry process							4	5	20
Service									
Ability to operate without increased maintenance requirements				0	1	0	3	5	15
Operational lifespan							2	5	10
Financial									
Ability to be used at no additional capital cost				0	5	0	4	7	28
Lifestyle									
Ability to be used without occupant noticing any change from current situation				0	5	0	5	10	50
Ability to improve the indoor environment	0	5	0	0	5	0	2	8	16
Policy									
Likelihood of becoming mandatory feature before 2016				0	10	0	4	10	40
Wider political sensitivities to this type of technology				0	1	0	5	5	25
Total rating	0.00		0.00	0.00		0.00	36.00		237.00
Success potential	0%		0%	0%		0%	48%		50%

Technology 7 Efficient heating circulators									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements	0	10	0	0	3	0	0	3	0
Ability to reduce domestic hot water requirements	0	10	0	0	7	0	0	7	0
Appliance load									
Ability to reduce appliance electrical load	0	10	0	0	10	0	0	10	0
Pumps and fans load									
Ability to reduce pumps and fans electrical load	0	10	0	0	3	0	5	3	15
Lighting load									
Ability to reduce lighting electrical load	0	10	0	0	5	0	0	5	0
Evidence									
Availability of suitable existing British or European testing Standards							2	5	10
Availability of test data				0	5	0	2	5	10
Installation									
Ability to be installed with current industry skills				0	5	0	4	7	28
Ability to be installed within current industry process							5	5	25
Service									
Ability to operate without increased maintenance requirements				0	1	0	5	5	25
Operational lifespan							2	5	10
Financial									
Ability to be used at no additional capital cost				0	5	0	5	7	35
Lifestyle									
Ability to be used without occupant noticing any change from current situation				0	5	0	5	10	50
Ability to improve the indoor environment	0	5	0	0	5	0	0	8	0
Policy									
Likelihood of becoming mandatory feature before 2016				0	10	0	0	10	0
Wider political sensitivities to this type of technology				0	1	0	3	5	15
Total rating	0.00		0.00	0.00		0.00	38.00		223.00
Success potential	0%		0%	0%		0%	51%		47%

Technology 8 Individual socket shutdown units									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements	0	10	0	0	3	0	0	3	0
Ability to reduce domestic hot water requirements	0	10	0	0	7	0	0	7	0
Appliance load									
Ability to reduce appliance electrical load	0	10	0	0	10	0	2	10	20
Pumps and fans load									
Ability to reduce pumps and fans electrical load	0	10	0	0	3	0	0	3	0
Lighting load									
Ability to reduce lighting electrical load	0	10	0	0	5	0	0	5	0
Evidence									
Availability of suitable existing British or European testing Standards							2	5	10
Availability of test data				0	5	0	2	5	10
Installation									
Ability to be installed with current industry skills				0	5	0	5	7	35
Ability to be installed within current industry process							5	5	25
Service									
Ability to operate without increased maintenance requirements				0	1	0	4	5	20
Operational lifespan							2	5	10
Financial									
Ability to be used at no additional capital cost				0	5	0	3	7	21
Lifestyle									
Ability to be used without occupant noticing any change from current situation				0	5	0	3	10	30
Ability to improve the indoor environment	0	5	0	0	5	0	0	8	0
Policy									
Likelihood of becoming mandatory feature before 2016				5	10	50	0	10	0
Wider political sensitivities to this type of technology				0	1	0	5	5	25
Total rating	0.00		0.00	5.00		50.00	33.00		206.00
Success potential	0%		0%	8%		16%	44%		43%

Technology 9 Advanced Real Time Displays									
Key features/issues	Stage of technology development								
	Academic/blue sky research			Prototype product			Market-ready product and manufacturing process		
	Rating								
	Initial	Weighting	Final	Initial	Weighting	Final	Initial	Weighting	Final
Heat loss									
Ability to reduce space heating requirements	0	10	0	1	3	3	0	3	0
Ability to reduce domestic hot water requirements	0	10	0	1	7	7	0	7	0
Appliance load									
Ability to reduce appliance electrical load	0	10	0	1	10	10	0	10	0
Pumps and fans load									
Ability to reduce pumps and fans electrical load	0	10	0	1	3	3	0	3	0
Lighting load									
Ability to reduce lighting electrical load	0	10	0	1	5	5	0	5	0
Evidence									
Availability of suitable existing BS or EN testing Standards							0	5	0
Availability of test data				1	5	5	0	5	0
Installation									
Ability to be installed with current industry skills				3	5	15	0	7	0
Ability to be installed within current industry process							0	5	0
Service									
Ability to operate without increased maintenance requirements				5	1	5	0	5	0
Operational lifespan							0	5	0
Financial									
Ability to be used at no additional capital cost				3	5	15	0	7	0
Lifestyle									
Ability to be used without occupant noticing any change from current situation				1	5	5	0	10	0
Ability to improve the indoor environment	0	5	0	2	5	10	0	8	0
Policy									
Likelihood of becoming mandatory feature before 2016				1	10	10	0	10	0
Wider political sensitivities to this type of technology				3	1	3	0	5	0
Total rating	0.00		0.00	24.00		96.00	0.00		0.00
Success potential	0%		0%	38%		30%	0%		0%

Appendix C
SAP 2009 modelling assumptions

This table provides an overview of the assumptions that were made regarding the implementation of each of the technologies considered; further details are provided on page 46.

SAP 2009		Appliances	Water heating	Space heating	Pumps and fans	Lighting	Photovoltaic generation	Total	Dwelling Emission Rate
70% carbon compliant home	Energy use (kWh/year)		1356	2763	478	386	-1245	3738	6.80
	Resultant CO_2 (kg)	1196	268	547	247	200	-658	2458	
Demand control ventilation	Energy use		1357	2474	375	386	-1245	3348	5.70
	Resultant CO_2	1196	269	490	194	200	-646	2348	
Adjustment: Reduce air change rate via Mechanical Ventilation and Heat Recovery from 0.5 to 0.05 air changes per hour for 12 h/day									
Whole house shutdown	Energy use		1356	2763	478	386	-658	4324	6.05
	Resultant CO_2	801	268	547	247	134	-658	1997	
Adjustment: Apply reduction factor of 0.67 to 'appliances' and 'lights' components of energy use									
Next-generation Light Emitting Diode lighting	Energy use		1356	2763	478	212	-1245	3564	5.60
	Resultant CO_2	1196	268	547	247	94	-658	2351	
Adjustment: Apply reduction factor of 0.55 to 'lights' components of energy use									
Shower Waste Water Heat Recovery	Energy use		602	2763	478	386	-658	3570	5.12
	Resultant CO_2	1196	119	547	247	200	-658	2308	
Adjustment: Use SAP Appendix Q, displace 754 kWh of gas use. Apply saving to water heating component of SAP calculation									
Passive Flue Gas Heat Recovery	Energy use		1153	2763	478	386	-1245	3535	6.34
	Resultant CO_2	1196	228	547	247	200	-658	2417	
Adjustment: Use SAP Appendix Q, displace 203 kWh of gas use. Apply saving to water heating component of SAP calculation									
Solar-assisted Positive Input Ventilation	Energy use		1356	2518	478	386	-1245	3493	6.25
	Resultant CO_2	1196	268	498	247	200	-658	2409	
Adjustment: Use SAP Appendix Q, displace 245 kWh of gas use. Apply saving to space heating component of SAP calculation									
Efficient heating circulators	Energy use		1356	2763	400	386	-1245	3660	6.34
	Resultant CO_2	1196	268	547	207	200	-658	2417	
Adjustment: Apply reduction factor of 0.4 to circulator component within SAP pumps and fans energy consumption calculation									
Individual socket shutdown units	Energy use		1356	2763	478	386	-1245	3738	6.80
	Resultant CO_2	801	268	547	247	200	-658	2063	
Adjustment: Appliances off for a third of the time. Apply reduction factor of 0.67 to 'appliances' component of energy use									
Advanced Real Time Displays	Energy use		1356	2763	478	363	-1245	3714	6.66
	Resultant CO_2	1124	268	547	247	188	-658	2374	
Adjustment: Apply reduction factor of 0.94 to 'Appliances' and 'Lights' components of energy use									

Demand control ventilation

The MVHR system was assumed to run at the standard rate of 0.5 air changes per hour for 12 hours per day and a much reduced setback rate of 0.05 air changes per hour for the remaining 12 hours of the day. The assessment of this technology was handled slightly differently to the other technologies as modelling the impact of reducing the ventilation rate is not possible in commercial SAP software such as NHER SAP 2009 Preview. Both SAP 2005 and SAP 2009 assume a fixed air change rate of 0.5 when MVHR is specified. In order to be able to change this figure BRE's SAP 2009 spreadsheet was used to create two scenarios of the typical dwelling, one of which used the default 0.5 air changes per hour ventilation rate and another in which the default was modified to 0.05 air changes per hour. The space heating energy use and fans portion of the SAP 'pumps and fans' energy use components were then averaged for the two scenarios.

Whole house shutdown

Appliances were assumed to be turned off completely during hours with no occupancy which was taken to be one third of the time (eight hours per day). A correction factor of 0.67 was applied to both the 'appliances' and 'lighting' output from SAP.

Next-generation Light Emitting Diode lighting

Best practice LED luminaire performance of 65 lm/W was assumed for all lighting, providing a 45% saving on the SAP lighting electricity use component. A correction factor of 0.55 was applied to the 'lighting' component of the SAP calculation.

Solar-assisted Positive Input Ventilation

It was assumed that the air coming from the solar-assisted unit is 5°C warmer than the external air, that the ventilation rate is the SAP default 0.5 air changes per hour and that the solar pre-heat is available half the time.

Efficient heating circulators

A rated heating pump is 60% more efficient than a regular pump. SAP 2005 and 2009 assumes a 60 W circulator running for 2000 hours per year, resulting in annual energy use of 130 kWh. A correction factor of 0.4 has been applied to the heating circulator component of the 'pumps and fans' electricity use component of SAP.

Individual socket shutdown units

Appliances were assumed to be turned off completely during hours with no occupancy which was taken to be one third of the time (eight hours per day). A correction factor of 0.67 was applied to the 'appliances' output from SAP.

Advanced Real Time Displays

Many assumptions on the possible savings of advanced RTDs have been quoted in various discussions and publications. The range appears to be an expected saving between 3.5% and 15% on energy use monitored by the device, ie the energy consumption made visible to occupants. For the purposes of this report, it has been assumed that for the midpoint a 6% saving is plausible. A correction factor of 0.94 was applied to both the 'appliances' and 'lighting' output from SAP.

References

1 DCLG. Building Regulations 2000, Conservation of fuel and power in new dwellings. Approved Document L1A. London, DCLG, 2006.

2 DCLG. Planning, building and the environment. www.communities.gov.uk/planningandbuilding (last accessed 11 October 2011) .

3 DECC. The Government's Standard Assessment Procedure for energy rating of dwellings. London, DECC, 2010.

4 Standard Assessment Procedure. http://projects.bre.co.uk/sap2005 (last accessed 11 October 2011).

5 The DCLG consultation for this definition is given in Definition of zero carbon homes and non-domestic buildings, CLG, December 2008. Note that the 70% reduction is calculation is based on slightly different assumptions from the SAP 2005 defaults, eg 100% CFL lighting is assumed present.

6 The NHER SAP 2009 Preview version 1.4 software used to produce this report may not fully reflect the final version of SAP 2009 released in October 2010.

7 Zero Carbon Hub. Carbon compliance – setting an appropriate limit for zero carbon new homes. London, Zero Carbon Hub, 2011.

8 HM Treasury. Budget – Plan for growth. London, HM Treasury, 2011.

9 US Department of Energy, CALiPER Benchmark Report – Performance of halogen incandescent MR16 lamps and LED replacements, November 2008.

10 Solid state lighting. US Department of Energy, 2009. www.eere.energy.gov/buildings/ssl/news_detail.html?news_id=12381 (last accessed 11 October 2011).

11 Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005. Official Journal of the European Union, 22 July, 2005.

12 DECC. Towards a smarter future: Government response to the consultation on electricity and gas smart metering. DECC Publications, 2009.

13 Consultation on proposed amendments to the Carbon Emissions Reduction Target 2008-2011, DECC, 2009. http://decc.gov.uk/en/content/cms/consultations/open/cert/cert.aspx (last accessed 11 October 2011).

14 Darby. The effectiveness of feedback on energy consumption. Oxford, Environmental Change Institute, 2006. www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf (last accessed 11 October 2011).

15 Standard Assessment Procedure (SAP 2009). www.bre.co.uk/sap2009/page.jsp?id=1642 (last accessed 11 October 2011).

NHBC Foundation recent publications

Prospects for the UK house-building industry

The research findings in this report outline which LZC technologies are currently being used and which of these technologies are becoming dominant (or not) in the new house-building sector. It also provides insight into home occupiers' actual day-to-day experiences and attitudes towards LZC technologies and how they are used in their homes. ***NF 42*** April 2012

Low and zero carbon homes: understanding the performance challenge

This report reviews the evidence that supports the existence of a CO_2 performance gap and explores its potential causes. It establishes that, contrary to some of the views expressed on the topic to date, there is no single cause. Instead the report identifies a multitude of possible causes and issues that may contribute, from the earliest stages of design through to post-construction checking. All of these issues need to be understood and dealt with if the CO_2 performance gap is to be minimised.
NF 41 February 2012

Today's attitudes to low and zero carbon homes

The first independent research of its kind, this primary research report assesses attitudes towards low and zero carbon homes – including research among people actually living in those homes. Find out what occupants really feel about living in highly energy efficient homes and the recommendations to industry to help deliver zero carbon homes and boost the demand and supply in the housing supply chain.
NF 40 i (executive briefing) and NF40 ii (full report) February 2012

NHBC Foundation publications can be downloaded from **www.nhbcfoundation.org**

NHBC Foundation publications in preparation

- Building sustainable homes at speed: Risks and rewards
- Recycled and secondary aggregate and cement replacement in residential construction
- Overheating in highly insulated homes

NHBC Foundation

Housing research in partnership with BRE Trust

www.nhbcfoundation.org

Energy efficient fixed appliances and building control systems

This report examines the range of energy efficient fixed appliances and building control systems that are either currently available or are under development, and considers how these might be incorporated into new low or zero carbon homes.

The report models energy consumption and CO_2 emissions from a home illustrative of those to be built from 2016, examines the performance of fixed appliances and building control systems, and identifies those that merit further investigation. Findings indicate that a number of the technologies examined offer significant potential for saving energy and reducing CO_2 emissions.

As we head towards the zero carbon future for new homes, and begin to address the huge challenge of reducing energy consumption, it is clear that the correct choice of energy-efficient technologies is likely to make a valuable contribution.

The NHBC Foundation has been established by NHBC in partnership with the BRE Trust. It facilitates research and development, technology and knowledge sharing, and the capture of industry best practice. The NHBC Foundation promotes best practice to help builders, developers and the industry as it responds to the UK's wider housing needs. The NHBC Foundation carries out practical, high quality research where it is needed most, particularly in areas such as building standards and processes. It also supports house builders in developing strong relationships with their customers.

43

Published by IHS BRE Press on behalf of the NHBC Foundation
ISBN 978-1-84806-182-8

NHBC FOUNDATION
Housing research in partnership with BRE Trust