A survey of low and zero carbon technologies in new housing

Primary Research

NHBC Foundation
Housing research in partnership with BRE Trust

Zero Carbon Hub

EPSRC
Engineering and Physical Sciences Research Council

University of Reading

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This work was undertaken in collaboration with the NHBC Foundation and the Zero Carbon Hub. The research was supported by the Engineering and Physical Sciences Research Council (EPSRC)-funded 'Innovative Construction Research Centre' (EP/E001645/1) and the EPSRC-funded 'Maximising the diffusion and impact of microgeneration technologies in new housing' (EP/H051104/1).

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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. Research has included a review of microgeneration and renewable energy techniques and the groundbreaking research on zero carbon and what it means to homeowners and housebuilders.

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:

Contents

Foreword

The Government has set a target for all new homes to be zero carbon from 2016. This poses a challenge for the UK house-building industry to produce sustainable homes with enhanced environmental performance. To meet these requirements after taking into account the building fabric, house builders are increasingly incorporating low and zero carbon (LZC) technologies to achieve the necessary on-site performance.

The recently published NHBC Foundation report *Today's attitudes to low and zero carbon homes: Views of occupiers, house builders and housing associations* (NF40) highlighted the need for LZC technologies that are reliable, perform to expectations and are capable of being used by home occupiers to achieve their design potential.

To provide further guidance on these issues, this publication investigates LZC technologies currently being used and likely to become dominant in the market. Through in-depth interviews with homeowners, carried out by the School of Construction Management and Engineering at the University of Reading, this research reports on their day-to-day use and attitudes towards these technologies.

The results support and expand on those published in NF40 and provide valuable information to assist the industry in developing and producing the LZC products that will be installed and used to meet the zero carbon target. As we know, the effectiveness of many of these new technologies depends on consumer understanding of how they work, and how to get the best value from them. So this report also provides information to help those tasked with developing the controls, information and training to assist the public in achieving the energy and costs efficiencies that the designer intended.

I hope you find the report informative and useful as it supports our continued activity in helping to shape the future development of zero carbon homes.

Rt. Hon. Nick Raynsford MP
Chairman, NHBC Foundation

Executive Summary

House builders in the United Kingdom are being challenged to produce homes with increasing levels of environmental performance in accordance with the Government's zero carbon agenda. For many builders, a key part of their compliance strategy is the selection and incorporation of low and zero carbon (LZC) technologies into new homes.

The research findings in this report are guided by two questions:

1. Which LZC technologies are currently being used and why these technologies are becoming dominant (or not) in the new house build sector?

2. What are the home occupiers actual day-to-day experiences of and attitudes towards different types of LZC technologies in their homes?

The research was conducted in two phases, each concentrating on one of the questions.

Phase 1: Which LZC technologies and why?

A nationwide survey of industry experts with a thorough knowledge and experience of LZC technologies was conducted. The questionnaire was designed around a set of innovation factors for the uptake and diffusion of new technologies: relative advantage, compatibility, complexity, trialability and observability. The key results are as follows:

- Solar based technologies (solar thermal and solar PV systems) have the highest degree of use, followed by mechanical ventilation and heat recovery and air source heat pumps.
- A wider range of LZC technologies are used on brownfield sites than greenfield sites and on conversion sites than brownfield sites. The use of solar thermal systems in particular see a drop off as the dwelling density increases and are used much less in apartments that in housing. Correspondingly biomass, renewable micro-combined heat and power and micro-combined heat and power systems see an increase in use in apartments compared to housing.
- Solar based systems score highly against all of the innovation factors, with the exception of the ease of which respondents can secure planning permission.
- Respondents are using a range of different LZC technologies although almost a third relies on one or two technologies only.
- There was strong consensus that the solar based technologies will play the most significant role leading up to and beyond 2016.
- A robust research approach to better understand the selection rationale used to identify low and zero carbon solutions has been established.

Phase 2: Lived-in experiences of LZC technologies

A series of interviews were conducted in the homes of people that live with LZC technologies to establish the actual day-to-day experiences of and attitudes towards different types of LZC technologies. The in-depth interviews not only consisted of questions, but actually observed occupiers using the user control panels to establish their practices and to compare them with the 'design' functionality of the technologies. A blueprint methodology for engaging with occupants to capture lived-in knowledge, experience and aspirations has been produced. Three main categories of occupier 'interaction' with LZC technologies became apparent: pre-occupation, every day use and future expectations. Occupiers exhibited distinct interests and behaviours in each category.

Pre-occupation

- General low awareness of the LZC technologies installed prior to occupation.
- Typically a lack of appropriate information for occupiers of the potential benefits of the LZC technologies from the housing developer marketing / sales teams.

Everyday use

- Occupiers were uncertain how the use of LZC technologies affected their energy bills.
- A proportion of the occupiers have changed their everyday routines to maximise the actual or perceived benefits of the installed LZC technologies.
- General lack of appropriate information provided to support occupiers in the day-to-day operation of the installed LZC technologies.
- Evidence of 'workarounds' from occupiers where they changed the actual operational performance of the LZC technology by altering their 'as designed' installation and, in so doing, reduced the operational performance of the technology.

Future expectations

- Diverse occupier reactions as to whether or not they would, based on their experiences, recommend friends and family members to consider LZC technologies.
- Lack of feedback mechanisms to capture occupiers' experiences of LZC technologies to enhance future housing designs and marketing approaches.

1 Introduction

The Government has laid down the requirement that all new homes will need to be zero carbon from 2016. In response, many house builders are selecting and incorporating new low and zero carbon technologies into their products.

From July 2010 the Zero Carbon Hub and NHBC Foundation have been working together with the School of Construction Management and Engineering at the University of Reading to address two research questions relating to this selection of low or zero carbon (LZC) technologies:

- which LZC technologies are currently being used and why are these technologies becoming dominant (or not) in the new house build sector?
- what are home occupiers actual day-to-day experiences of and attitudes towards different types of LZC technologies in their homes?

This report presents the findings of the work addressing the first question (phase 1) and the interim findings relating to the second question (phase 2). The full findings for phase 2 will be presented in a subsequent report once the research has been concluded in the latter part of 2012.

2 Methodology

This section presents the approach taken in each of the two phases.

2.1 Phase 1

A web-based survey was conducted. The design of the survey was based on the following factors for the uptake and diffusion of new technologies:

- *Relative advantage* – the degree to which a given LZC technology is perceived by the house builder as being better than other alternative LZC solutions.
- *Compatibility* – the amount to which a LZC technology is perceived to build upon the house builder's existing capabilities.
- *Complexity* – the level to which a LZC technology is perceived by the house builder as relatively difficult to understand and use compared to other alternative LZC solutions.
- *Trialability* – the extent to which a LZC technology may be experimented with by the house builder on a limited basis prior to wider roll-out compared to other alternative LZC solutions.
- *Observability* – the degree to which the results or the benefits of a LZC technology are visible to the house builder compared to other alternative LZC solutions.

The survey contained both open and closed questions to establish the current use of LZC technologies. In this work LZC technologies are defined as any technologies, additional to the fabric of the building envelope, which generate or recover energy.

The LZC technologies selected for this study are those identified in the NHBC (2008) *Review of microgeneration and renewable energy technologies*. We questioned the effect of site type (greenfield, brownfield and conversion), dwelling type (house, apartments and mixed use) and location on the selection of LZC technologies. A series of questions based on the innovation criteria were then asked to understand the rationale for the selection and use of each of the technologies. Finally, we sought participants' views on which LZC technologies might be used in the future.

The survey sample set was aimed at gathering opinions of industrialists with specialist knowledge and thorough experience of LZC technologies, as they are the most likely to guide which technologies are taken up by the housing sector. This type of 'purposive sampling' allows the data to be used confidently with low response rates, as is typically the case with this type of survey. The results are not intended to be representative of the sector as a whole.

The opportunity to participate in the survey was distributed to those people on the lists of the NHBC Foundation and Zero Carbon Hub who expressed an interest in sustainability when they registered to receive an e-news bulletin. The survey captured a wide range of views from different parts of the sector, including large and small house builders (both in terms of number of employees and units built per year), different regions in the UK, diverse job roles and different levels of seniority. Participants self-selected themselves, through responding to the e-mail invitation, to take part in the survey.

The survey was distributed by the NHBC Foundation and Zero Carbon Hub to approximately 12,000 potential participants and 64 usable responses were received (out of 108 responses in total). This is a response rate of less than 1%. The reason for this low response rate is of interest, given the importance of LZC technologies, but is outside the scope of this report. The purposive sampling strategy, however, provides interesting results nonetheless.

2.2 Phase 2

In contrast to phase 1, the second phase of the work adopted a qualitative approach. A series of semi-structured interviews and open-ended discussions were conducted with occupants. Occupants were contacted to take part in the study by the housing developer or social landlord. During these sessions with the occupants they were encouraged to discuss features of their new homes with the interviewers taking notes, observations and photographs.

The goal of the research was to establish the day-to-day lived-in experiences of occupants relating to the LZC technologies – to get underneath the skin of what their understanding and use (or non-use!) of the technologies. Conducting the sessions in the home allowed the occupants to demonstrate their actual knowledge of and experience with the LZC technologies in their home. This authentic setting allowed a deeper, richer understanding to be developed compared to 'arms length' questionnaires and focus groups which often exhibit the weakness of revealing what respondents think they should say and do, rather than what they actually believe and do.

To guide the sessions a series of broad areas were covered. These included a discussion relating to the occupants' dwelling history, a 'day in the life' of the household, a 'year in the life of the household', and the benefits and frustrations of the LZC technology in their new home. No closed questions were asked as the occupants were allowed to lead the interview and shape the direction of the questioning to avoid as much as possible constraining the field of enquiry.

2.3 Report structure

This work is presented in two separate sections: Phase 1 and Phase 2.

Phase 1: Which LZC technologies and why?

The demographics of the survey are presented to give an indication as to the range and type of respondents. Then, for each of the LZC technologies, a profile is presented. Each profile contains information relating to the extent of the use of that technology for unit type and site type combination along with the factors underpinning its selection.

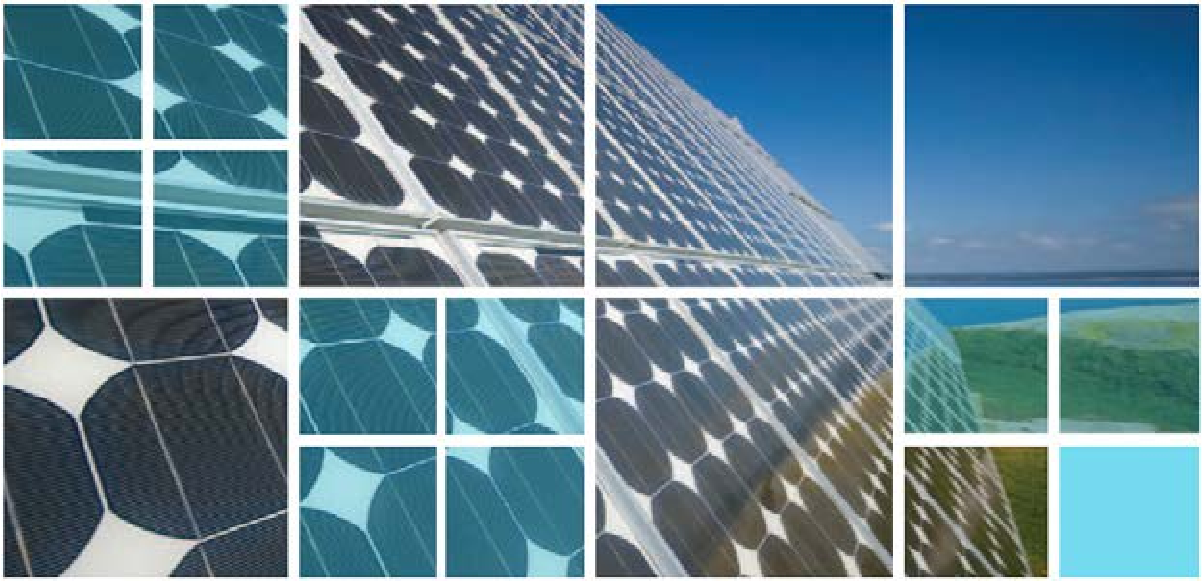
For each of the profiles, the responses to the innovation factors influencing the selection of the technology are expressed in absolute terms (as a percentage of respondents indicating favourable for that factor) and as a relative score where 12 points is the maximum and 1 the minimum when the responses for a particular technology are ranked. To further assist the bars are colour coded into quartiles (green the highest, red the lowest).

Both the technology use and the factors shaping their selection are then summarised followed by a short discussion of particularly interesting aspects of the data.

Phase 2: Lived in used experiences of LZC technologies

The interim results for this phase of the work are presented in the following way. First, each housing development case study is introduced and summarised. Second, findings are presented with supporting quotes from occupants structured around pre-purchase, everyday use and future purchase expectations sections.

3 Phase 1: Which low and zero carbon technologies and why?



This section presents the results and discussion relating to which LZC technologies are currently being used and why these technologies are becoming dominant (or not) in the new house build sector. A summary of the raw data is given in Appendix A.

3.1 Demographics – who responded to the survey?

The regions in which the respondents were building are well distributed, with a slight emphasis on the South East and London. The number of respondents in each region is shown in Figure 1. Respondents were often active in more than one region.

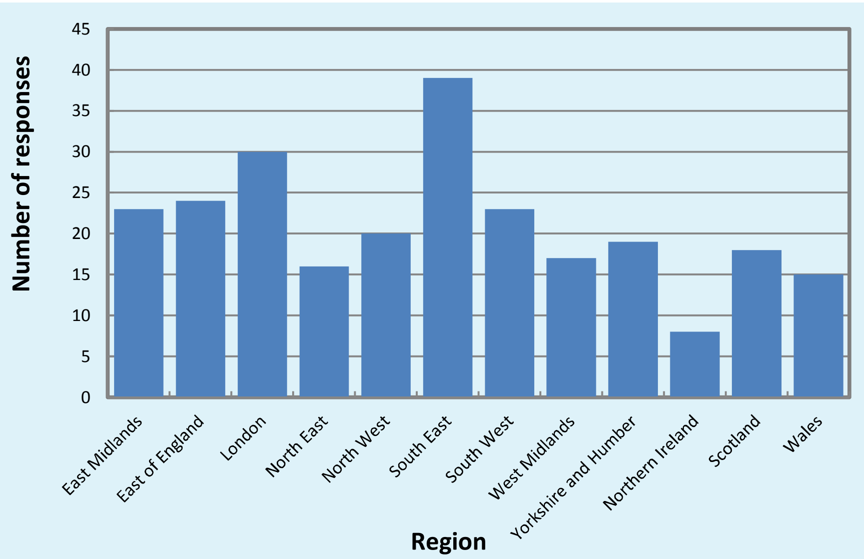


Figure 1 The number of respondents building in each region.

The largest number of respondents identified with the job role of 'design', 'other' and "construction" respectively. Responses collected against the 'other' category included procurement, project management, research and sustainability roles. The number of respondents indicating each job role is shown in Figure 2.

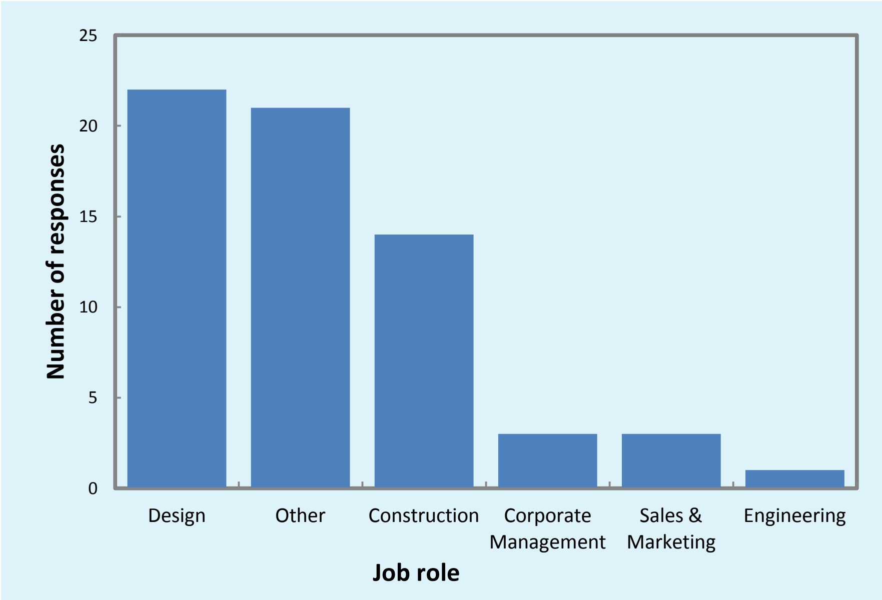


Figure 2 The number of respondents indicating particular job roles.

Respondents came from house builders with a range of number of employees and range of number of units produced. They did however tend to come from an organisation that either worked locally (one or two regions) or nationally (eleven or twelve regions). This is illustrated in Figure 3.

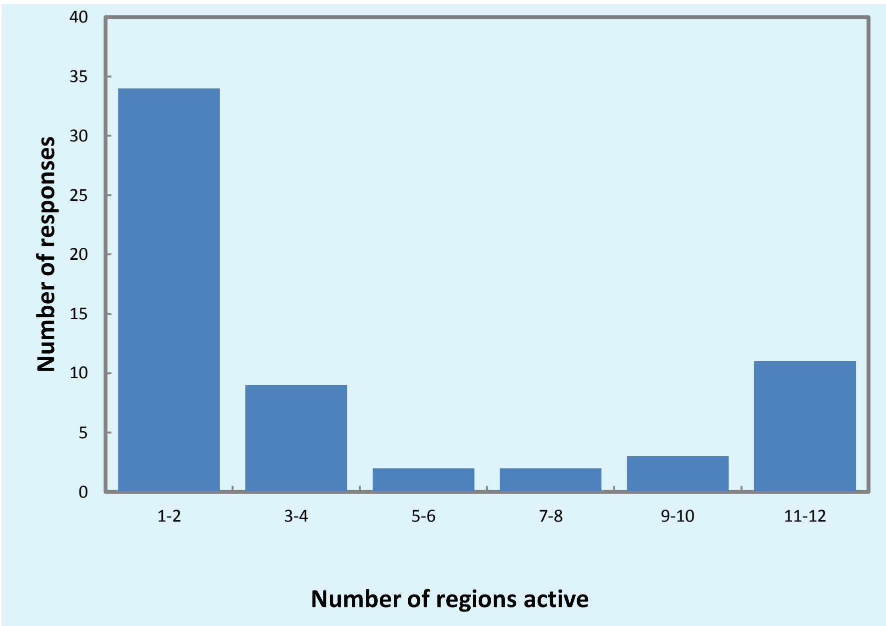


Figure 3 The number of regions in which the respondents indicated the company they work for were active in.

3.2. Technology profiles

The following section of the report presents a technology profile for each of the twelve technologies in the survey. The use of each technology was investigated for different unit types (terraced, semi-detached, detached houses and apartments up to three floors and above three floors) across three different site types (greenfield, brownfield and conversion sites). In these profile technology use is quoted as 'positive percentage' (see Appendix B). The individual technology data is then combined to make comparison easier.

Although technology use does vary from unit type to unit type and site to site it is possible to establish an aggregated 'overall usage.' This is the percentage of respondents who use this technology irrespective of the unit types they build and site types they develop. In Figure 4 the technologies are ranked from those used by most of the respondents on the left-hand side of the figure to those used least on the right-hand side. The technologies are also colour coded green for the three used most; yellow for the next three; orange for the next; and, red for the three used least.

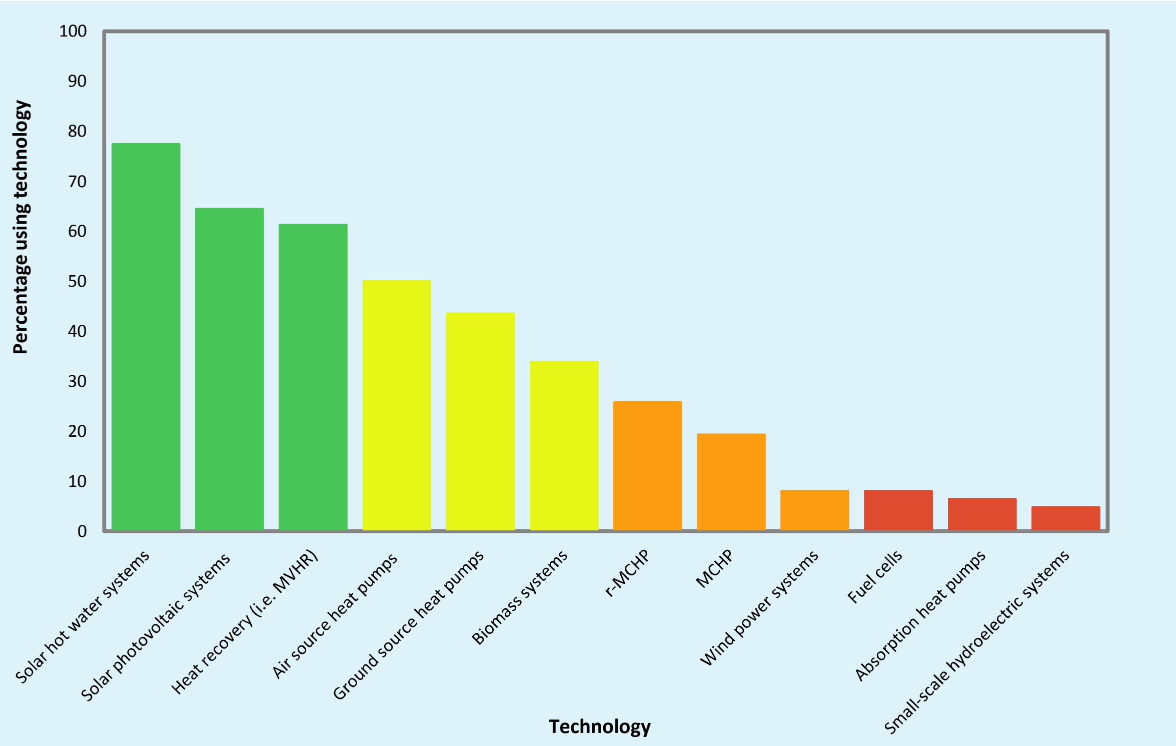


Figure 4 Overall usage of low and zero carbon technologies irrespective of unit and site type ranked from most to least used by respondents.

When ranked in this way the drop off in the number of respondents using a technology is surprisingly uniform from one technology to the next. However, there are four technologies that over 50 percent of the respondents are using (solar thermal, solar PV, heat recovery and air source heat pumps) and four technologies which less than 10 percent of the respondents have adopted (wind power, fuel cells, absorption heat pumps and small-scale hydroelectric systems). The remaining four technologies are between 10 and 50 percent. Technology profiles are presented for the eight technologies used by most of the respondents.

Solar photovoltaic systems

SOLAR PHOTOVOLTAIC SYSTEMS use photovoltaic (PV) cells to convert the energy of sunlight directly into electricity. Individual cells offer low voltages so they are often grouped together into panels which themselves can be grouped into arrays. These are typically fitted onto roofs which in the northern hemisphere are optimally orientated southwards and at a particular angle to the ground. PV cells can also be moulded into materials such as tiles and slates which can be integrated into a building. The energy generated from solar PV systems can be used at the time of the generation or sold back into the grid using the Feed-in Tariff (FIT).

Solar PV systems are used widely across all three site types. They are one of the most popular technologies (see Figure 5): 66 percent of respondents on greenfield sites used solar PV systems; 78 percent on brownfield sites; and, 59 percent on conversion sites. Overall 65 percent of respondents used solar PV systems.

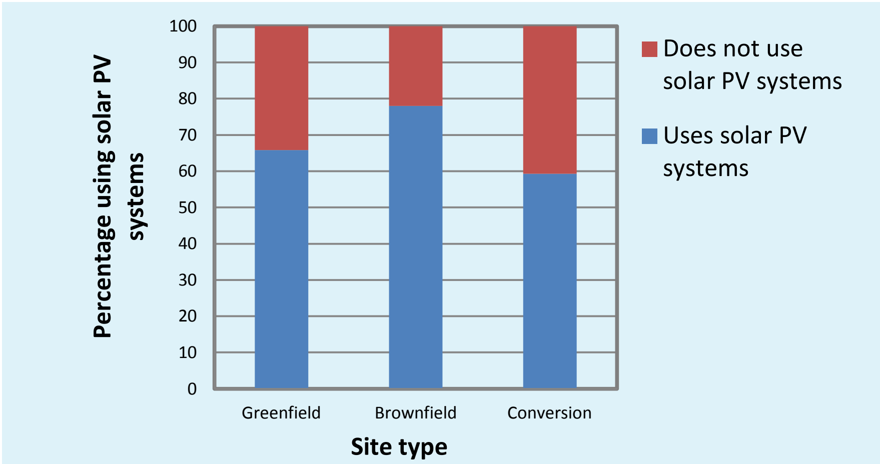


Figure 5 Percentage of respondents that indicated they use solar PV systems on different site types.

Figure 6 shows the percentage of respondents using solar PV systems for a range of different unit types. Across the unit types from the left-hand side to right-hand side the housing density increases.

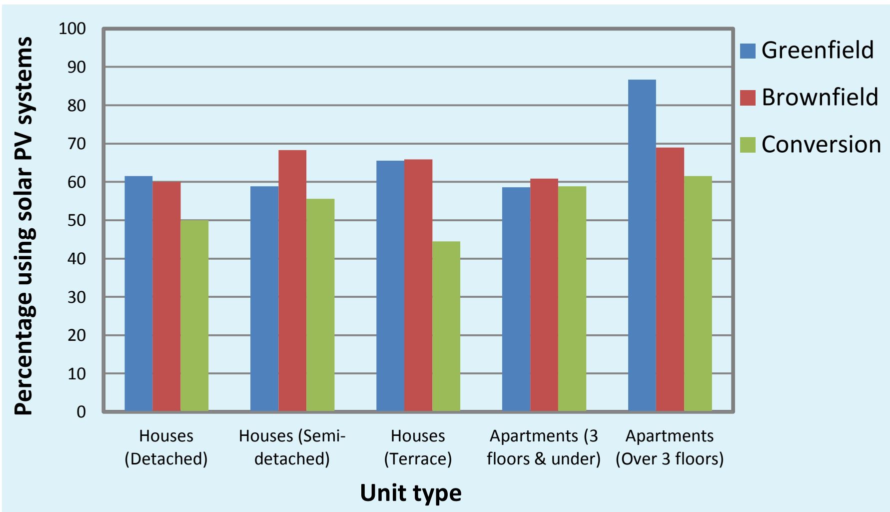


Figure 6 Percentage of respondents using solar PV systems.

Solar photovoltaic systems

There appears to be a number of innovation factors contributing to the popularity of solar PV systems which score highly (above 50 percent) in all the categories tested. PV systems scored the highest against ease of installation, use and maintenance which were followed closely by anticipation that this technology would decrease in price and play a significant role leading up to zero carbon in 2016. Figure 7 shows the absolute positive percentages returned against a range of categories.

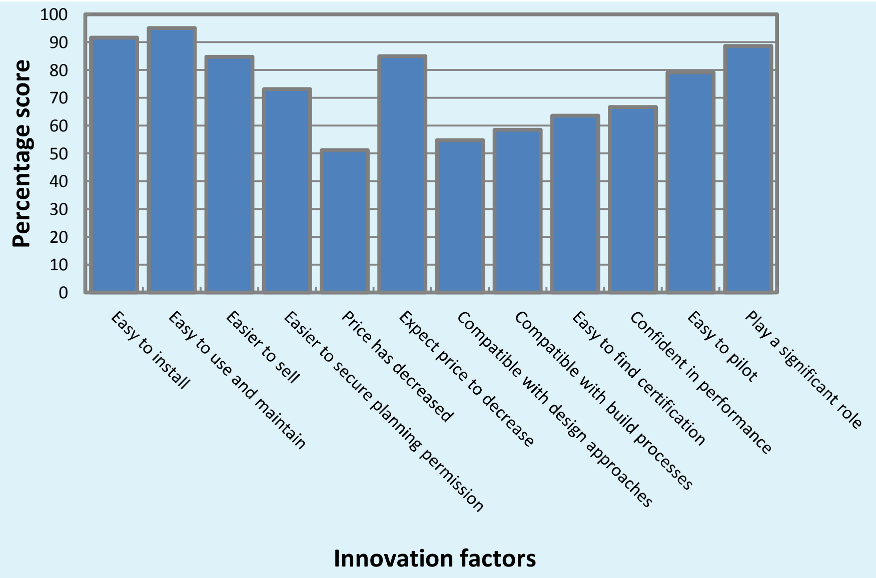


Figure 7 Percentage positive score for each factor for solar PV systems.

In Figure 8 the absolute scores are used to create a points system in which the highest response scores 12 points and the lowest 1 point. PV systems scored in the top quartile against eleven out of the twelve criteria tested and in the second quartile for the remaining criteria.

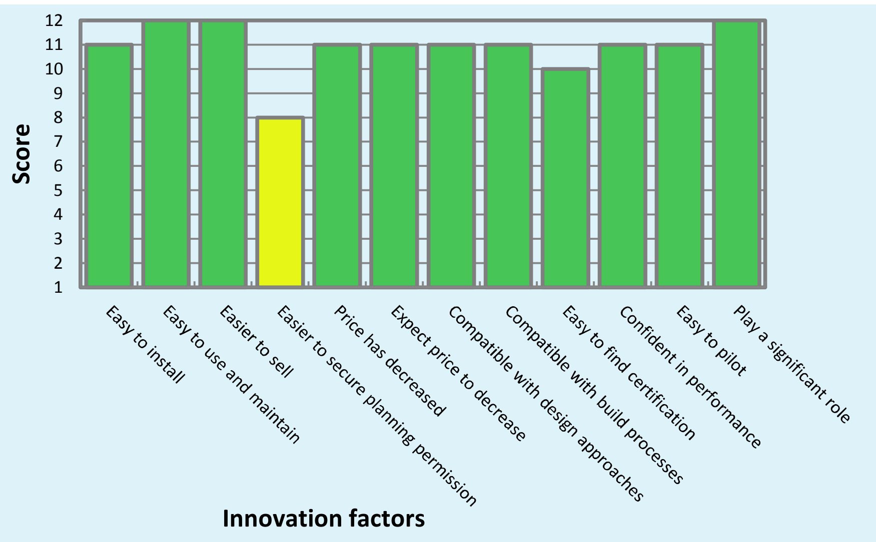


Figure 8 Ranking score for each factor for solar PV systems (12 highest, 1 lowest).

Solar thermal systems

SOLAR THERMAL SYSTEMS use solar collector panels to absorb solar radiation. This energy is used to heat water which is circulated through the hot water cylinder to pre-heat the water in the cylinder. A separate, auxiliary heat source is required to further increase the temperature of the water to a usable level. Most domestic solar thermal systems fall into the category of an 'indirect system' in which the water heated by the solar radiation does not come into contact with the usable water stored in the cylinder. As with PV systems, best results are achieved with south-facing roofs.

Solar thermal systems are used widely across all three site types. They are one of the most popular technologies (see Figure 9): 66 percent of respondents on greenfield sites used solar PV systems; 75 percent on brownfield sites; and, 63 percent on conversion sites.

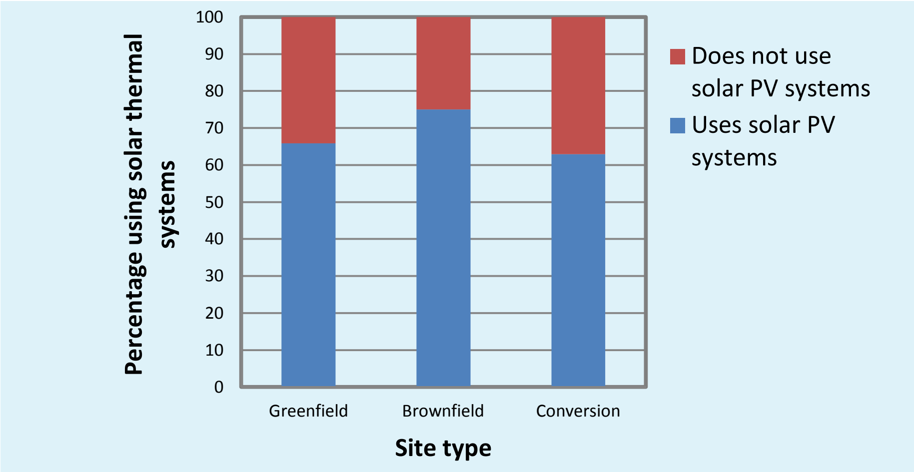


Figure 9 Percentage of respondents that indicated they use solar thermal systems on different site types.

Figure 10 below shows the percentage of respondents using solar thermal systems for a range of different unit types. Across the unit types from the left-hand side to the right-hand side the housing density increases.

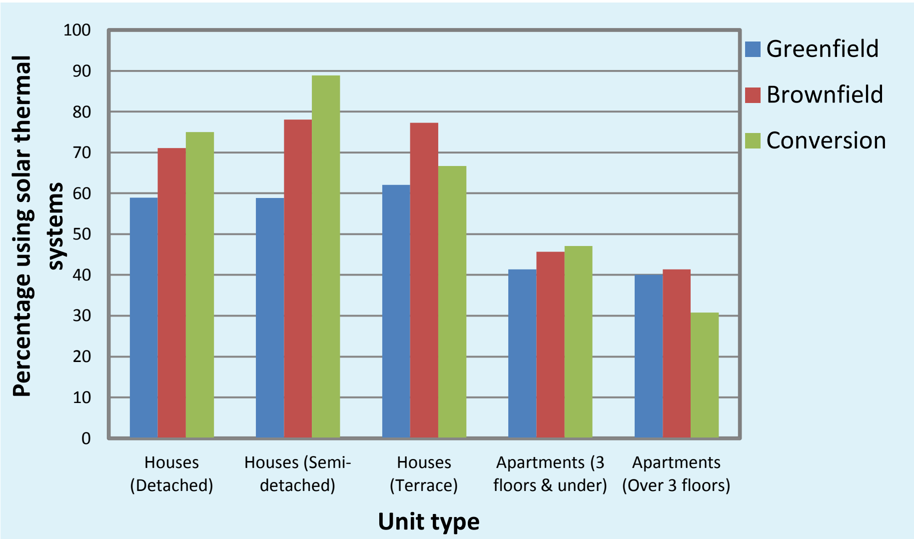


Figure 10 Percentage of respondents indicating they use solar thermal systems for different unit types.

Solar thermal systems

Solar hot water systems recorded high scores (above 50 percent) against all of the innovation factors tested. The categories with the highest absolute scores were the ease of installation, use and maintenance and lowest the decrease in price of the technology and compatibility with design approaches and build processes. Figure 11 shows the absolute positive percentages returned against a range of innovation factors.

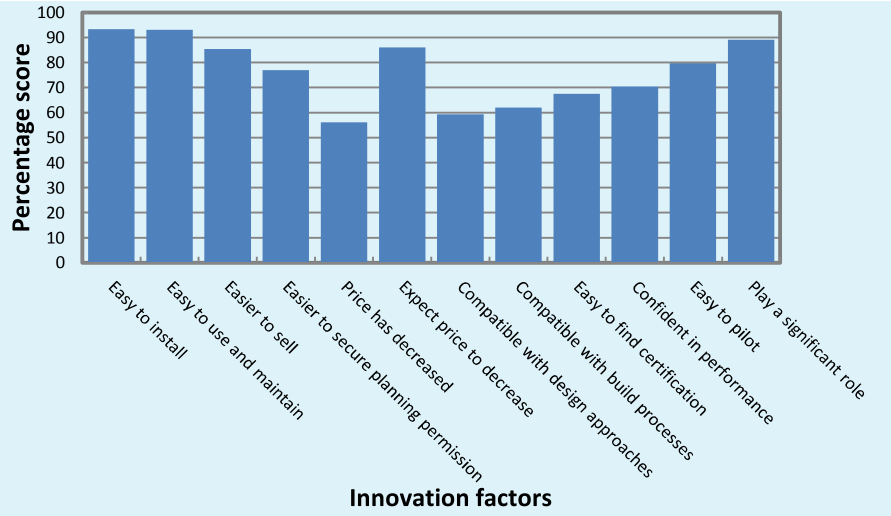


Figure 11 Percentage positive score for each factor for solar thermal systems.

When the scores for these categories are ranked against the other technologies, solar thermal systems perform very strongly as shown in Figure 12. Solar thermal ranks in the top quartile for all but one of the categories (securing planning permission) and highest in ten of the remaining eleven. This includes compatibility with both design approaches and build processes. This indicates that although potentially disruptive in absolute terms to current practices, solar thermal offers the least disruptive alternative to house builders.

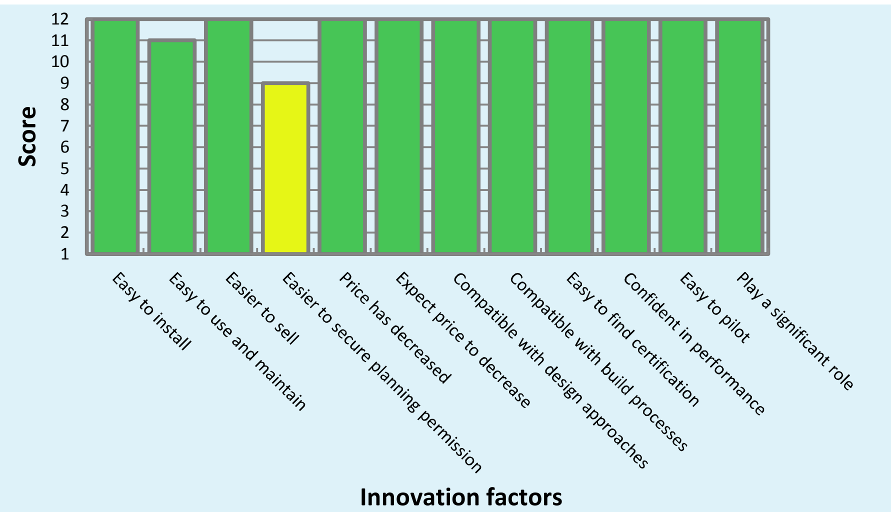


Figure 12 Ranking score for each factor for solar thermal systems (12 highest, 1 lowest).

Heat recovery systems

MECHANICAL VENTILATION AND HEAT RECOVERY systems are typically used in dwellings with high degrees of air tightness. The heat in warm, stale exhaust air is exchanged with incoming cooler, fresh air. The mechanical ventilation and heat recovery (MVHR) unit therefore serves two purposes. First, to keep the dwelling suitably ventilated. Second, to recover energy in the form of heat from the air that is being vented.

MVHR systems were moderately popular (see Figure 13): 44 percent of respondents used them on greenfield sites; 61 percent on brownfield sites; and, 39 on conversion sites. Overall, 50 percent of respondents used MVHR.

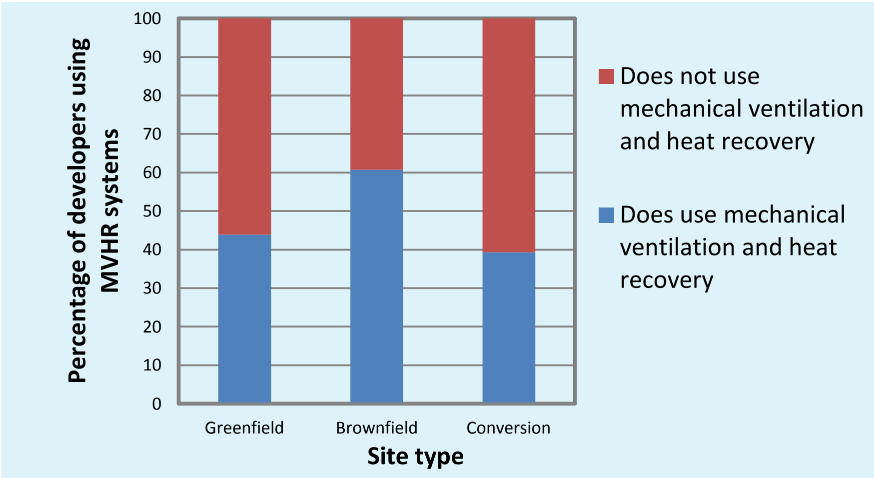


Figure 13 Percentage of respondents that indicated they use MVHR systems on different site types.

Figure 14 shows the percentage of respondents using MVHR systems for a range of different unit types. Across the unit types from the left-hand side to the right-hand side the housing density increases.

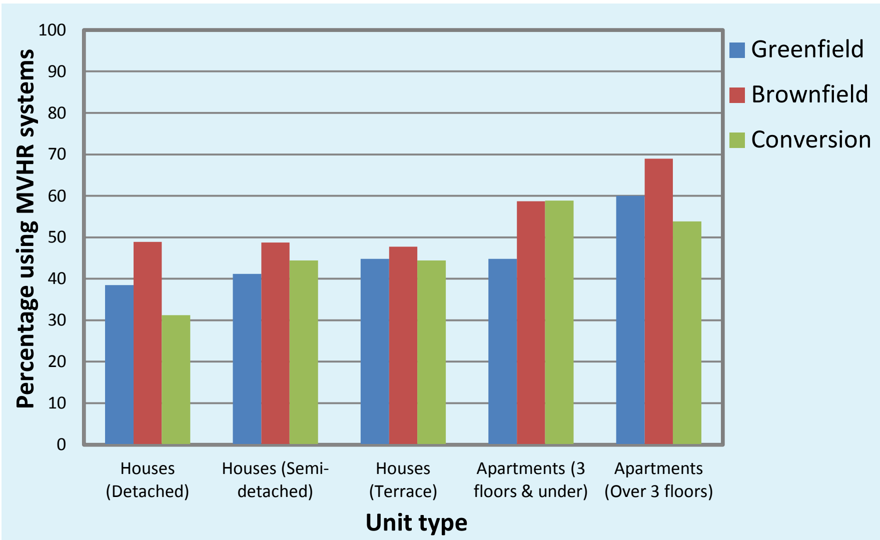


Figure 14 Percentage of respondents indicating they use MVHR systems for different unit types.

Heat recovery systems

MVHR systems scored highly (above 50 percent) in most categories although responses were lower than for the solar based technologies, particularly in relation to ease of installation, use and maintenance. MVHR systems returned a very high response in relation to the ease of securing planning permission. Figure 15 shows the absolute positive percentages returned against a range of categories.

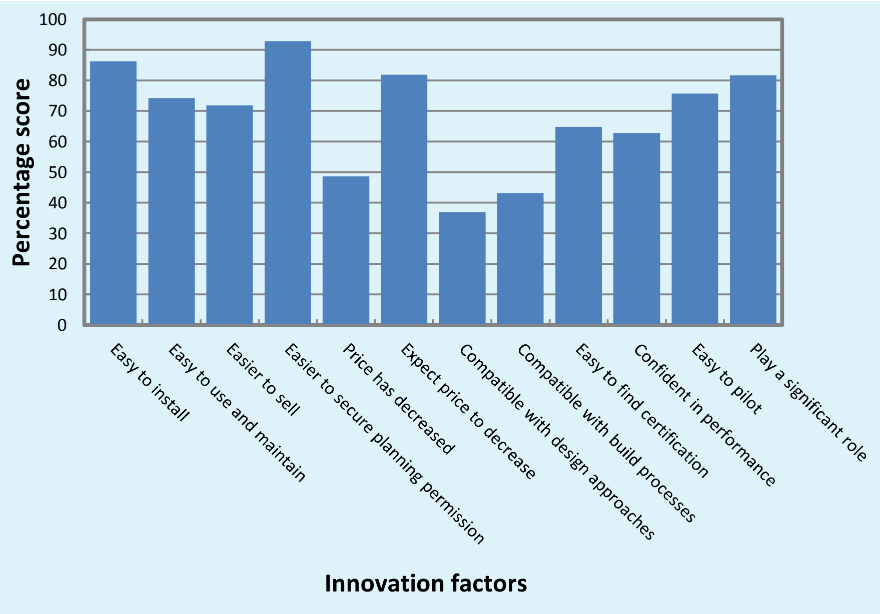


Figure 15 Percentage positive score for each factor for MVHR systems.

When the responses for MVHR systems were ranked against the other technologies it consistently ranked highly as shown in Figure 16. In most cases, MVHR ranked just below the two solar technologies. MVHR scored more highly than the solar technologies when considering impact on planning permission.

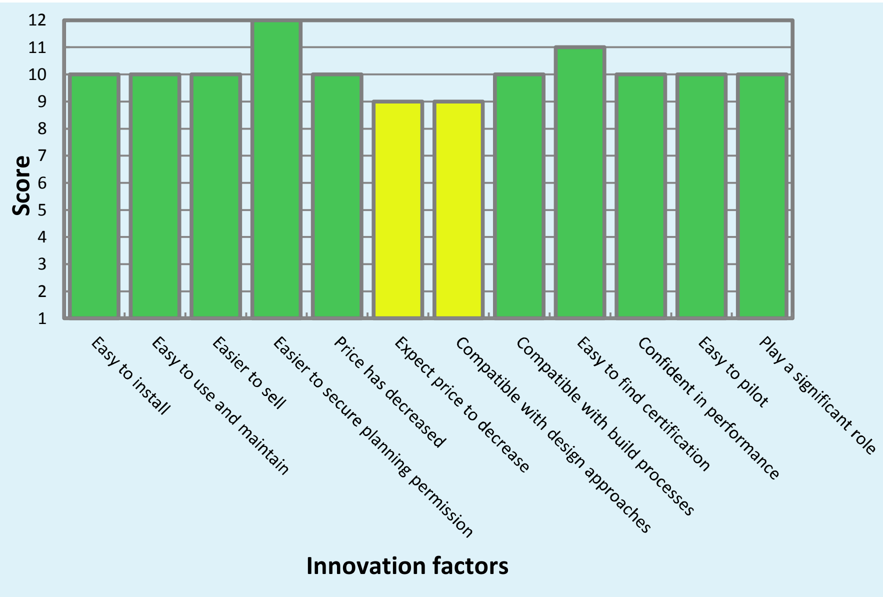


Figure 16 Ranking score for each factor for MVHR systems (12 highest, 1 lowest).

Air source heat pumps

AIR SOURCE HEAT PUMPS (ASHP) use principles similar to a refrigerator to move low-grade energy from outside, upgrade it to a more useful temperature and distribute it inside the dwelling. In ASHPs the low-grade energy comes from the surrounding air by using a fan to circulate outside air over a heat exchanger. The internal heat exchange can occur with the air inside the dwelling (distributed through a series of ducts and grilles) or with water to form the basis of the dwelling's heating system.

Overall, ASHP systems were moderately popular (see Figure 17): 44 percent of respondents used ASHP systems on greenfield sites, 46 percent on brownfield and 29 percent on conversion sites. Overall, 50 percent of respondents indicated that they use ASHP systems.

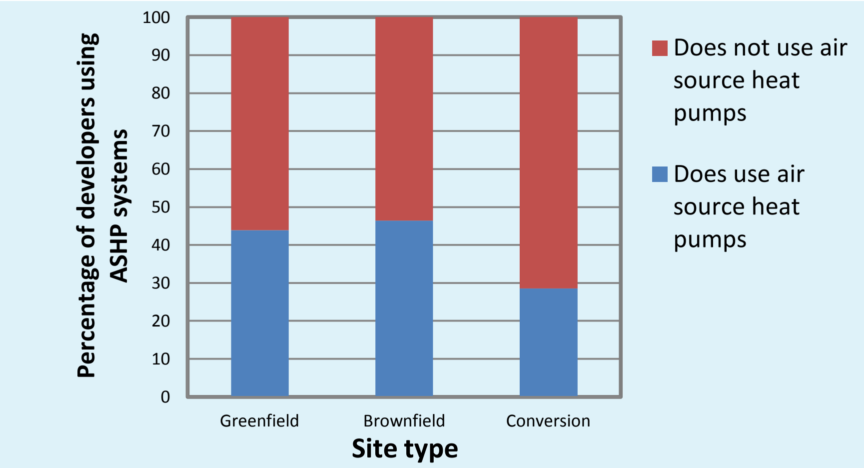


Figure 17 Percentage of respondents that indicated they use ASHP systems on different site types.

Figure 18 shows the percentage of respondents using ASHP systems for a range of different unit types. Across the unit types from the left-hand side to the right-hand side the housing density increases.

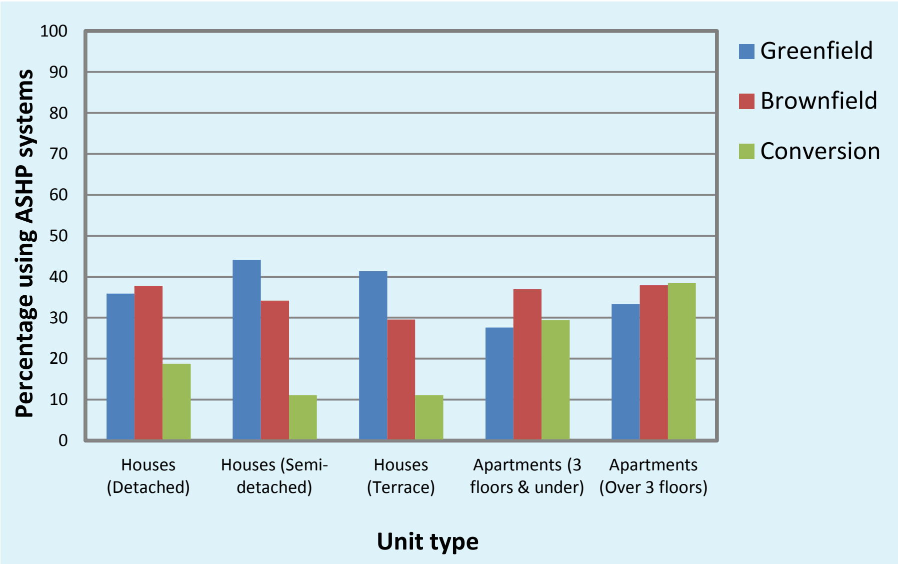


Figure 18 Percentage of respondents indicating they use ASHP systems for different unit types.

Air source heat pumps

ASHP systems scored highly (above 50 percent) in a number of categories. In every factor ASHPs scored less than solar based systems. The difference was largest for ease of sale, ease of use and maintenance and compatibility with design practise and build processes. Figure 19 shows the absolute positive percentages returned against a range of categories.

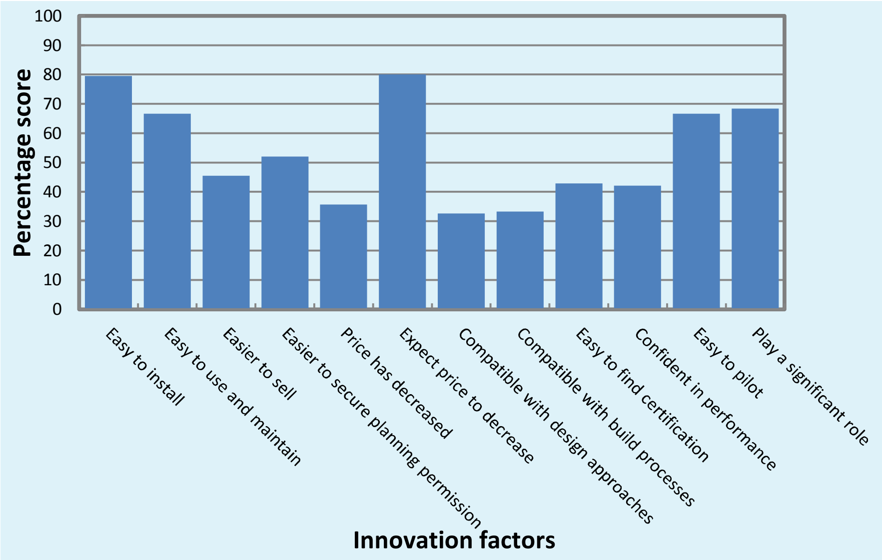


Figure 19 Percentage positive score for each factor for ASHP systems.

ASHP systems score almost completely in the second highest quartile when ranked against the other technologies, as shown in Figure 20. They score particularly poorly against the ease of securing planning permission category.

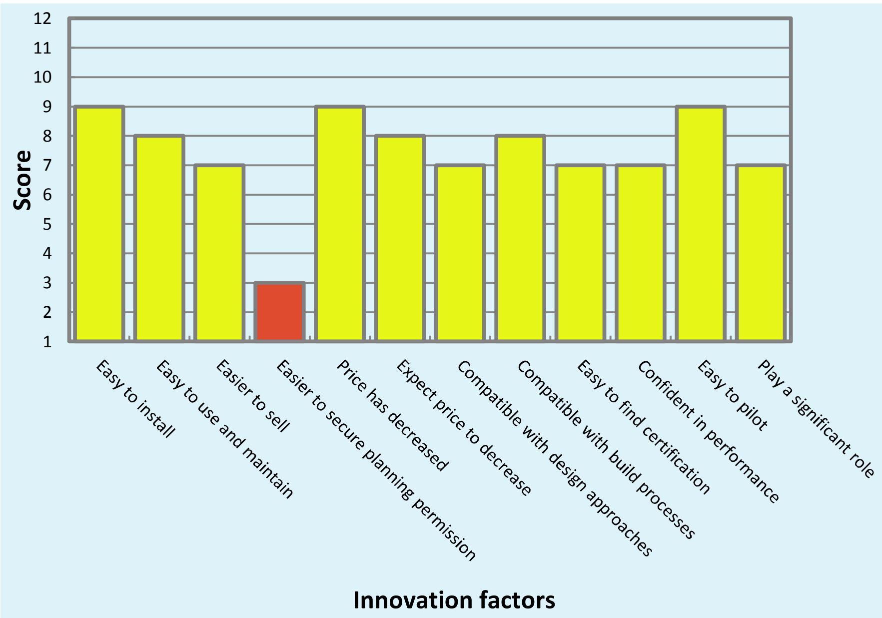


Figure 20 Ranking score for each factor for ASHP systems (12 highest, 1 lowest).

Ground source heat pumps

GROUND SOURCE HEAT PUMPS (GSHP) use principles similar to ASHP. In the case of GSHP the low energy is harvested from the ground rather than the air. This provides several advantages over ASHP as the temperature of the ground does not vary as much as air temperature both over a 24 hour period or seasonally. It is more typical for GSHP to exchange their high-grade heat with water to either form the basis of the heating system or to supply the domestic hot water.

Overall, GSHP systems were moderately popular (see Figure 21): 32 percent of respondents used ASHP systems on greenfield sites, 36 percent on brownfield and 29 percent on conversion site. Overall, 44 percent of respondents indicated that they use GSHP systems.

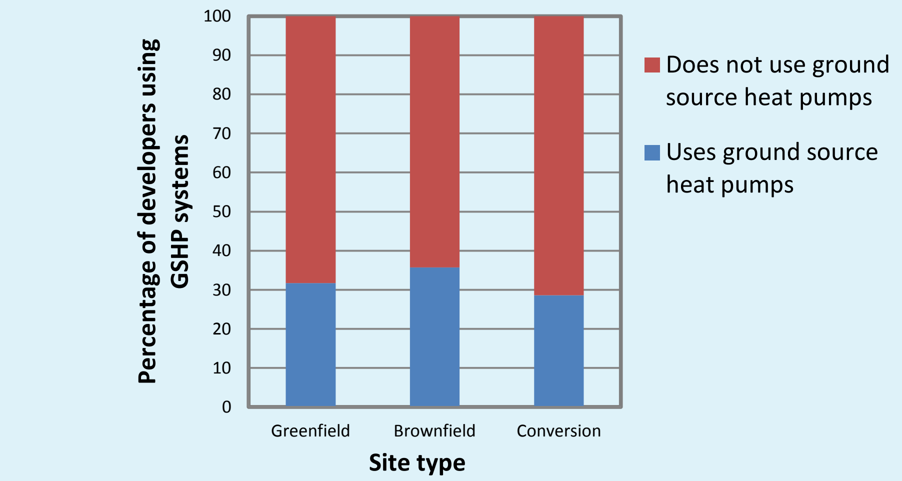


Figure 21 Percentage of respondents that indicated they use GSHP systems on different site types.

Figure 22 shows the percentage of respondents using GSHP systems for a range of different unit types. Across the unit types from the left-hand side to the right-hand side the housing density increases.

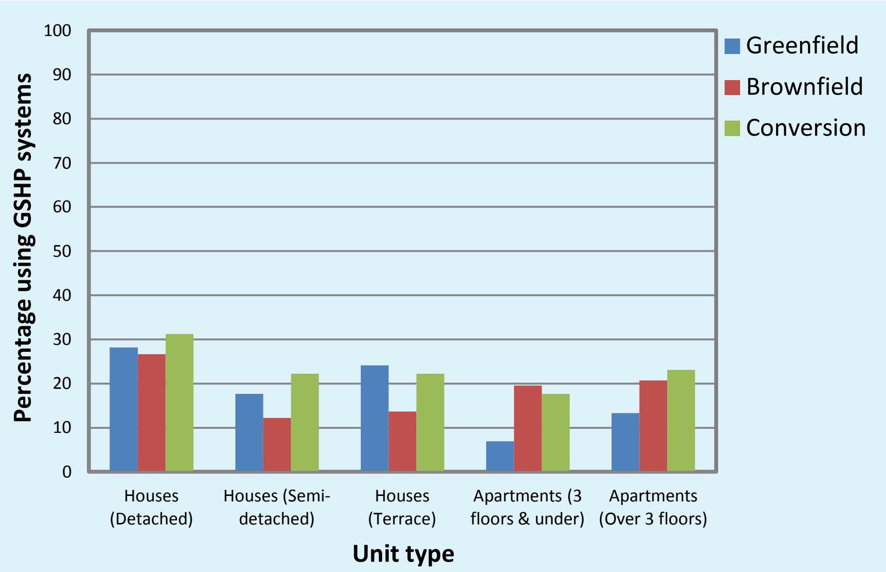


Figure 22 Percentage of respondents indicating they use GSHP systems for different unit types.

Ground source heat pumps

GSHP systems scored highly (above 50 percent) in five out of the twelve categories. In every factor, other than ease of securing planning permission, GSHP systems scored less than solar based systems. The difference was largest for ease of sale, ease of installation, use and maintenance. Figure 23 shows the absolute positive percentages returned against a range of categories.

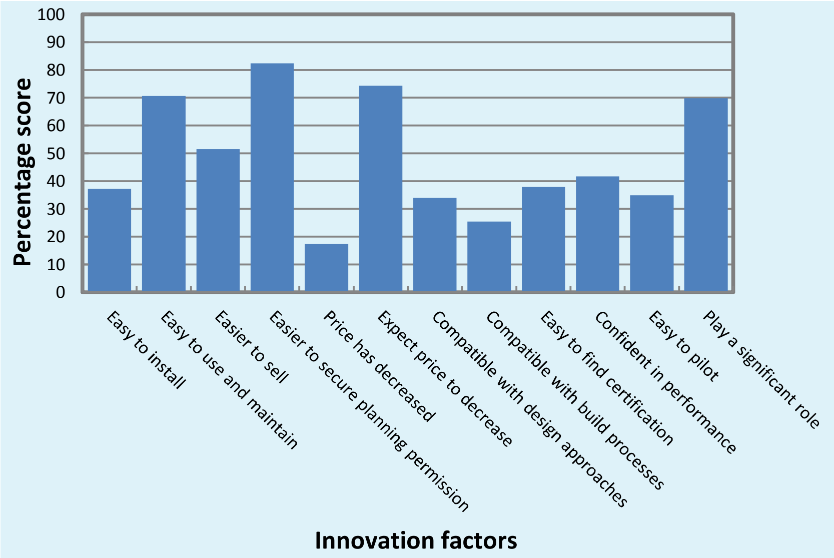


Figure 23 Percentage positive score for each factor for GSHP systems.

GSHP systems scored in the top quartile for ease of securing planning permissions, the second highest quartile for four other categories and the bottom two quartiles for the remaining categories, as shown in Figure 24.

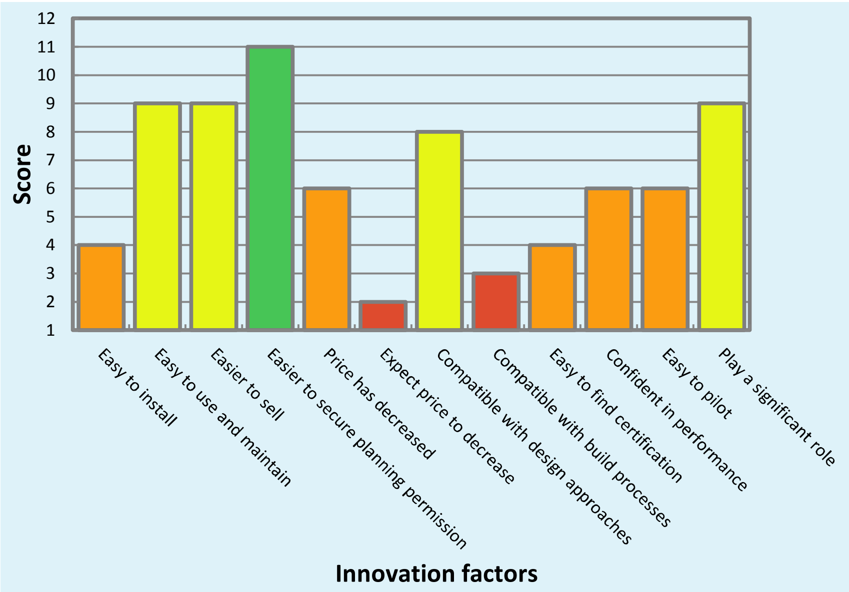


Figure 24 Ranking score for each factor for GSHP systems (12 highest, 1 lowest).

Biomass systems

BIOMASS SYSTEMS derive their energy from combusting biofuel. Typically this is wood logs but at some scales can be wood chip or pellets. Biomass is only sustainable if the fuel is sourced from managed woodland in which the trees are replaced once felled. Examples of biomass technologies which are suitable for domestic application include log stoves, ranges, pellet stoves, log boilers and pellet boilers.

Biomass systems were moderately popular on greenfield and brownfield sites (see Figure 25): 32 percent of respondents used biomass on greenfield sites, 32 percent on brownfield sites and zero percent on conversion sites. Overall, 34 percent of respondents used biomass systems.

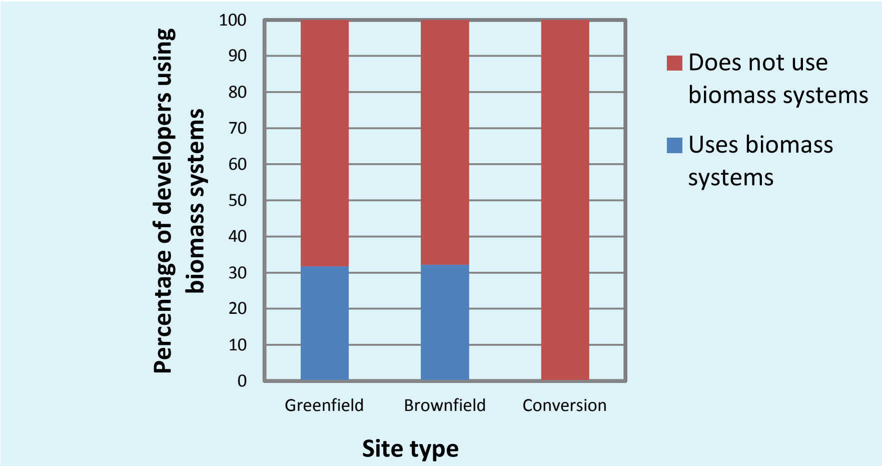


Figure 25 Percentage of respondents that indicated they use biomass on different site types.

Figure 26 shows the percentage of respondents using biomass for a range of different unit types. Across the unit types from the left-hand side to the right-hand side the housing density increases.

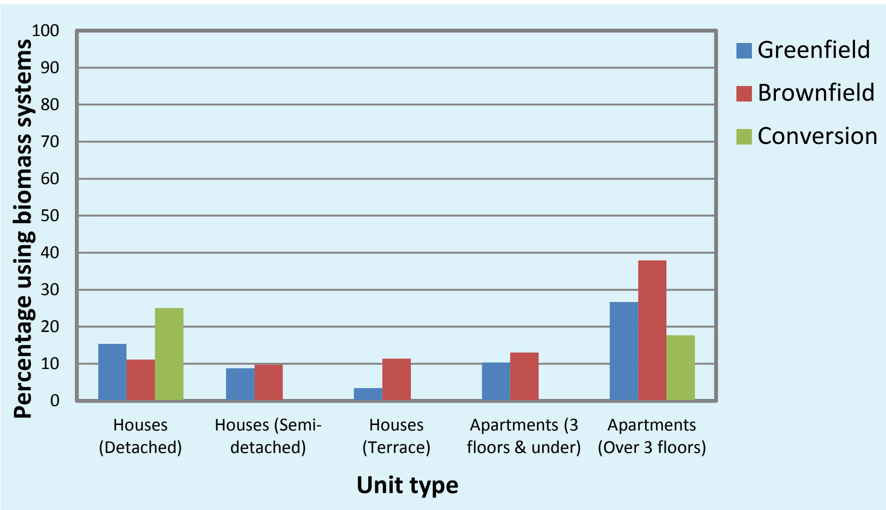


Figure 26 Percentage of respondents indicating they use Biomass systems for different unit types.

Biomass systems

Biomass systems scored poorly (below 50 percent) in nine out of the twelve categories. In every category biomass systems scored less than solar based systems. The difference was largest for ease of sale, ease of installation, use and maintenance. Figure 27 below shows the absolute positive percentages returned against a range of categories.

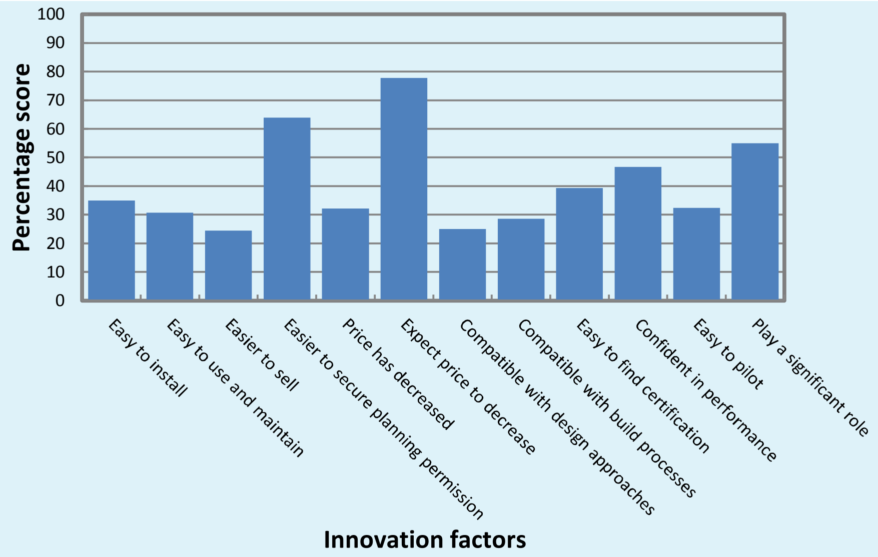


Figure 27 Percentage positive score for each factor for biomass.

Biomass systems scored in the bottom third quartile for seven out of the twelve categories, as shown in Figure 28. One category (Price has decreased) was in the second quartile and the remaining four categories were in the bottom quartile.

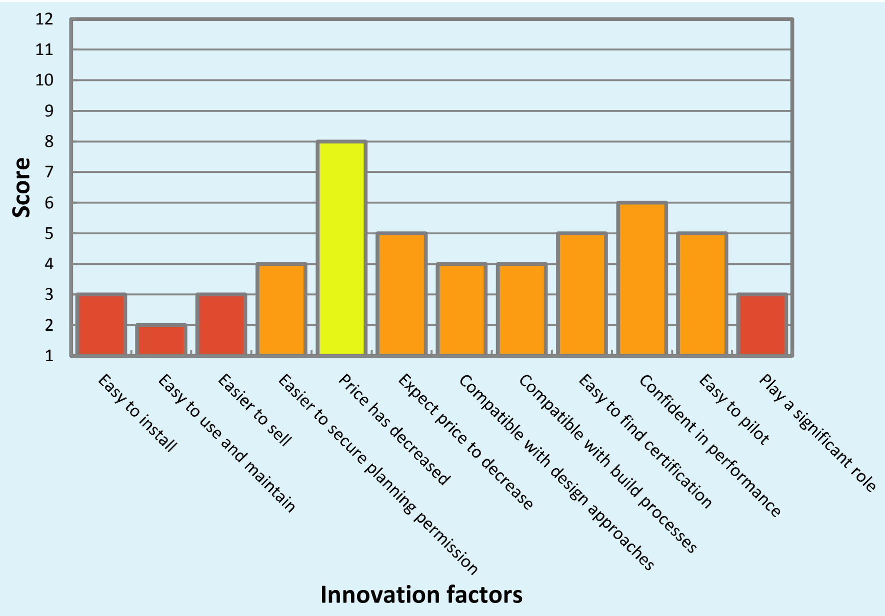


Figure 28 Ranking score for each factor for biomass (12 highest, 1 lowest).

Renewable micro-combined heat and power systems

RENEWABLE MICRO-COMBINED HEAT AND POWER (r-MCHP) systems are micro-combined heat and power systems which use biofuels rather than the conventional gas or oil used in traditional systems. Biofuels include biogas, wood and farm waste. Currently r-MCHP systems typically operate at the community scale as it is difficult to specify systems for individual dwellings. The ongoing increase in the performance of the building envelope, resulting in a lower overall energy consumption, means that r-MCHP is likely to remain a community scale solution.

r-MCHP systems are not widely used (see Figure 29): 10 percent of respondents indicated that they used r-MCHP systems on greenfield sites; 21 percent on brownfield sites; and, 21 percent on conversation sites. Overall, 26 percent of respondents indicated that they use r-MCHP systems.

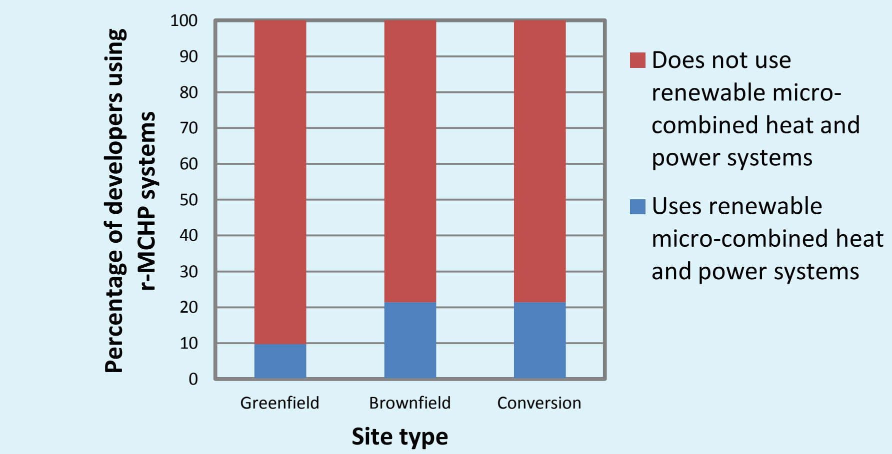


Figure 29 Percentage of respondents that indicated they use r-MCHP systems on different site types.

Figure 30 shows the percentage of respondents using r-MCHP systems for a range of different unit types. Across the unit types from the left-hand side to the right-hand side the housing density increases.

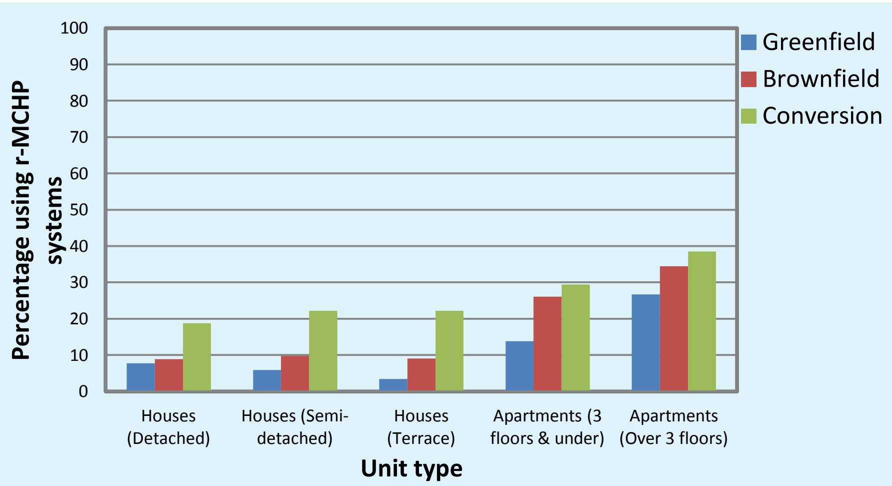


Figure 30 Percentage of respondents indicating they use r-MCHP systems for different unit types.

Renewable micro-combined heat and power systems

r-MCHP systems scored poorly (below 50 percent) in nine out of the twelve categories. In every category r-MCHP systems scored less than solar based systems. The difference was largest for ease of use and maintenance and ease of piloting. R-MCHP scored highly against the category of how significant a role respondents expected the technology to play in the future. Figure 31 shows the absolute positive percentages returned against a range of categories.

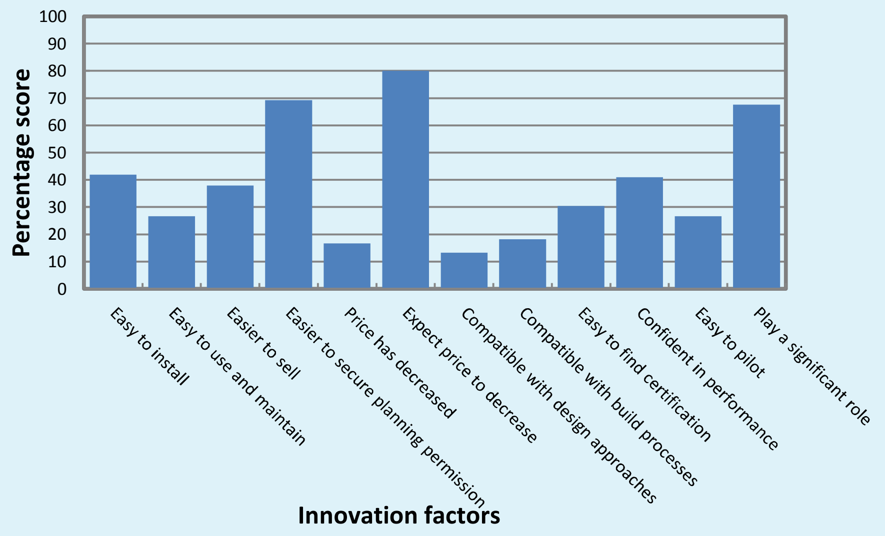


Figure 31 Percentage positive score for each factor for r-MCHP systems.

r-MCHP systems scored in the third lowest quartile for five of the twelve categories and in the lowest quartile for a further five categories as shown in Figure 32. The remaining two categories are in the second quartile.

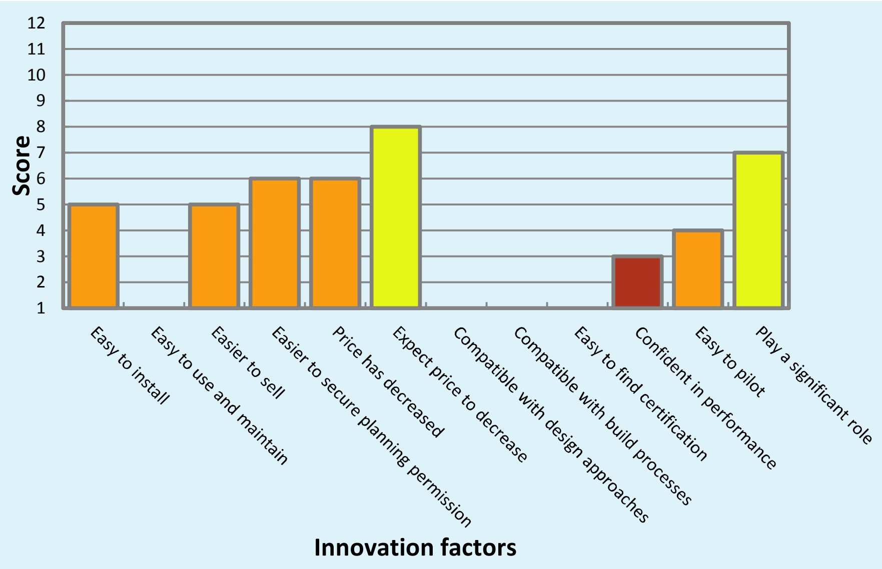


Figure 32 Ranking score for each factor for r-MCHP systems (12 highest, 1 lowest).

Micro-combined heat and power systems

MICRO-COMBINED HEAT AND POWER SYSTEMS (MCHP) are presented as a direct replacement for the gas boiler. The system generates electricity as well as heat for space heating and hot water. Typically MCHP systems run on natural gas. Aside from the fuel and electricity connections, the main elements of a CHP installation consist of a prime mover, an alternator, a heat recovery system and a control system. There are several types of prime mover used in MCHP systems but the two most common for the domestic sector are the Stirling engine and the internal combustion engine.

MCHP systems are not currently widely used (see Figure 33): 7 percent of respondents used MCHP systems on greenfield sites; 16 percent on brownfield sites; and, 25 percent on conversion site. Overall, 19 percent of respondents used MCHP systems.

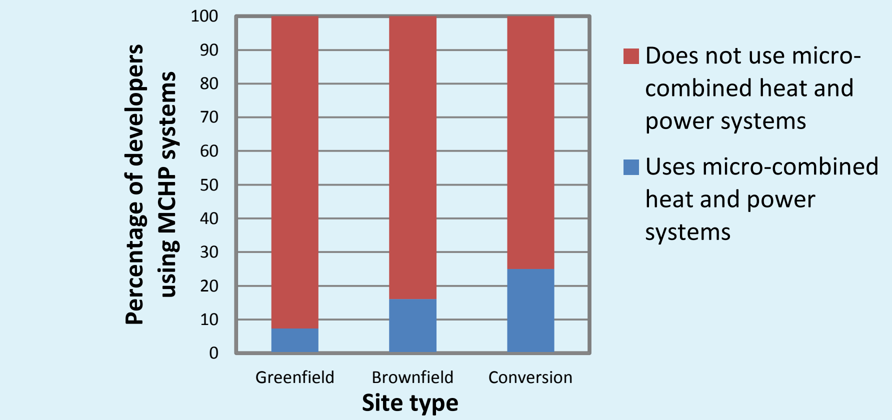


Figure 33 Percentage of respondents that indicated they use MCHP systems on different site types.

Figure 34 shows the percentage of respondents using MCHP systems for a range of different unit types. Across the unit types from the left-hand side to the right-hand side the housing density increases.

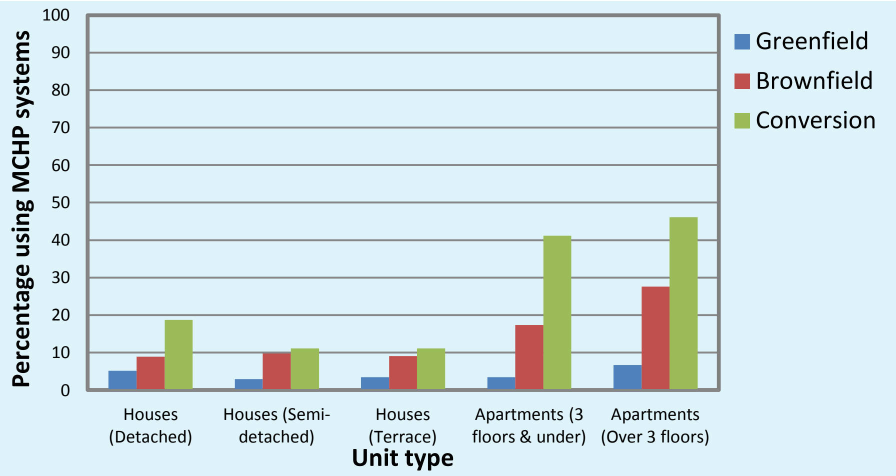


Figure 34 Percentage of respondents indicating they use MCHP systems for different unit types.

Micro-combined heat and power systems

MCHP systems scored poorly (below 50 percent) in seven out of the twelve categories. In every category MCHP systems scored less than solar based systems. The difference was largest for ease of use and maintenance and ease of piloting.   MCHP scored more highly against a number of categories compared to r-MCHP. Figure 35 shows the absolute positive percentages returned against a range of categories.

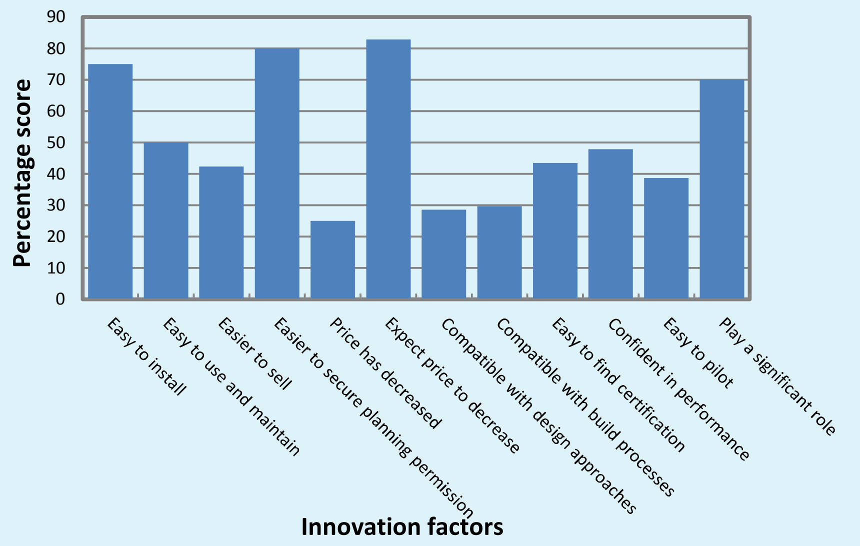


Figure 35 Percentage positive score for each factor for MCHP systems.

MCHP systems scored in the second highest quartile for seven of the twelve categories and in the highest quartile for a further two categories, as shown in Figure 36. The remaining three categories are in the third lowest quartile.

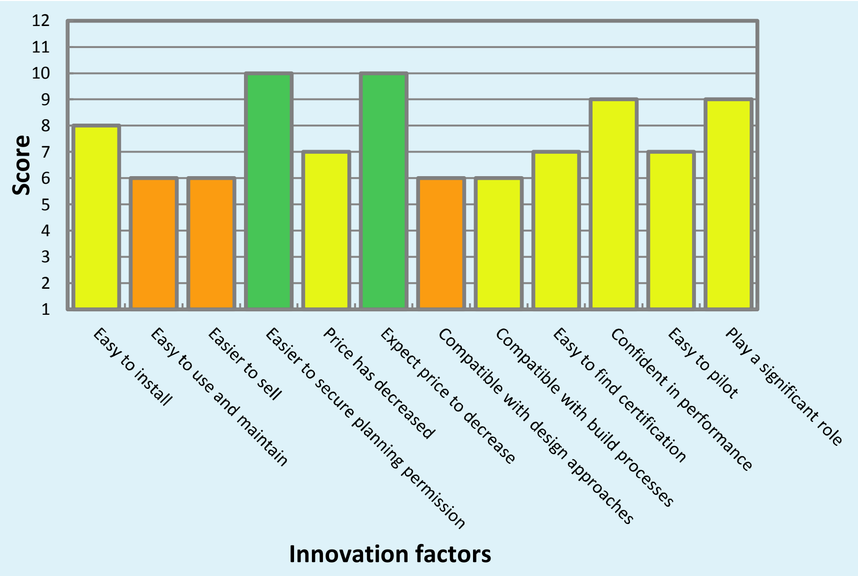


Figure 36 Ranking score for each factor for MCHP systems (12 highest, 1 lowest).

3.3. Discussion

The technology profiles set out in Section 3.2 provide evidence for the degree of use of LZC technologies. In order to compare the difference from one technology to another and across site and unit type the responses for each technology are shown in Figure 37. Here the percentage of respondents who use each technology, on a particular site and for a particular unit type, are shown. To help in drawing comparisons across the data each square in which the data points sits are colour coded against a graduated colour scale. The lowest value (0) is red and the highest value (89) is green. The same graduated scale is applied across the whole figure so comparisons across rows and down columns are equally valid.

	Site and unit type														
	Greenfield					Brownfield					Conversion				
	House			Apartment		House			Apartment		House			Apartment	
Technology	Detached	Semi-detached	Terraced	Upto 3 floors	Over 3 floors	Detached	Semi-detached	Terraced	Upto 3 floors	Over 3 floors	Detached	Semi-detached	Terraced	Upto 3 floors	Over 3 floors
Solar hot water systems	59	59	62	41	40	71	78	77	46	41	75	89	67	47	31
Solar photovoltaic systems	62	59	66	59	87	60	68	66	61	69	50	56	44	59	62
Heat recovery (i.e. MVHR)	38	41	45	45	60	49	49	48	59	69	31	44	44	59	54
Air source heat pumps	36	44	41	28	33	38	34	30	37	38	19	11	11	29	38
Ground source heat pumps	28	18	24	7	13	27	12	14	20	21	31	22	22	18	23
Biomass systems	15	9	3	10	27	11	10	11	13	38	25	0	0	0	18
Renewable micro-combined heat and power	8	6	3	14	27	9	10	9	26	34	19	22	22	29	38
Micro-combined heat and power	5	3	3	3	7	9	10	9	17	28	19	11	11	41	46
Wind power systems	5	3	3	3	7	7	2	2	4	3	13	11	22	6	8
Fuel cells	0	0	3	0	0	2	0	0	4	7	6	0	0	12	15
Absorption heat pumps	0	0	0	0	0	2	0	0	2	3	11	11	6	15	6
Small-scale hydroelectric systems	0	0	0	0	0	2	2	2	2	3	6	0	0	0	0

Figure 37 Percentage of respondents that use each LZC technology on particular site type for each dwelling type. A graduated colour scale has been applied across the whole figure from red (0) to green (89).

There are a number of trends which can be cautiously identified in the patterning above.

The solar based technologies (solar thermal and solar PV systems) have the highest degree of use followed by MVHR and ASHP systems.

The spread of green and yellow across the technologies (indicating a higher level of use) increases from greenfield to brownfield to conversion sites. This indicates that there might be a wider range of LZC technologies used on brownfield sites than greenfield sites and on conversion sites than brownfield sites. Possibly this may be due to the complexity of developing on these sites. The complexity of developing on the sites increases from greenfield to brownfield to conversion and this could potentially demand a greater range of LZC solutions.

Within each site type there are some trends from one unit type to another. This is particularly prevalent in three technologies:

- solar thermal systems see a drop off in use as the dwelling density increases and are used much less in apartments that in housing;
- biomass systems see an increase in use in apartments compared to housing; and,
- r-MCHP (and MCHP) sees an increase in use in apartments compared to housing.

Figure 38 highlights these trends. The arrowed lines show the trend in the use of technologies and the dotted square boxes highlight some of the differences in technology in apartments compared to houses.

	Site and unit type														
	Greenfield					Brownfield					Conversion				
	House			Apartment		House			Apartment		House			Apartment	
Technology	Detached	Semi-detached	Terraced	Upto 3 floors	Over 3 floors	Detached	Semi-detached	Terraced	Upto 3 floors	Over 3 floors	Detached	Semi-detached	Terraced	Upto 3 floors	Over 3 floors
Solar hot water systems	59	59	62	41	40	71	78	77	46	41	75	89	67	47	31
Solar photovoltaic systems	62	59	66	59	87	60	68	66	61	69	50	56	44	59	62
Heat recovery (i.e. MVHR)	38	41	45	45	60	49	49	48	59	69	31	44	44	59	54
Air source heat pumps	36	44	41	28	33	38	34	30	37	38	19	11	11	29	38
Ground source heat pumps	28	18	24	7	13	27	12	14	20	21	31	22	22	18	23
Biomass systems	15	9	3	10	27	11	10	11	13	38	25	0	0	0	18
Renewable micro-combined heat and power	8	6	3	14	27	9	10	9	26	34	19	22	22	29	38
Micro-combined heat and power	5	3	3	3	7	9	10	9	17	28	19	11	11	41	46
Wind power systems	5	3	3	3	7	7	2	2	4	3	13	11	22	6	8
Fuel cells	0	0	3	0	0	2	0	0	4	7	6	0	0	12	15
Absorption heat pumps	0	0	0	0	0	2	0	0	2	3	11	11	6	15	6
Small-scale hydroelectric systems	0	0	0	0	0	2	2	2	2	3	6	0	0	0	0

Figure 38 The percentage of respondents that use each LZC technology on particular site types for each of dwelling types. (A graduated colour scale has been applied across the whole figure from red (0) to green (89). The blue arrowed lines indicate the spread of technology use and the dotted blue squares highlight the differences between responses from housing to apartments.)

To compare the innovation factors that affect technology, Figure 39 shows a similar presentation of the data. The percentage of positive responses against that criterion is given and as in the figure above a colour coding is applied. However, this time the range of the colour coding is restricted to the column. This means each column will have a red square (the lowest value) and a green square (the highest value) and the values in between will be graduated against this scale. In this figure green indicates the highest response and red the lowest but not in absolute terms. The technologies are ranked from those with the largest number of respondents using them at the top to those with the least number at the bottom.

		Factor											
Technology	Technology use	Easy to install	Easy to use and maintain	Easier to sell	Easier to secure planning permission	Price has decreased	Expect price to decrease	Compatible with design approaches	Compatible with build processes	Easy to find certification	Confident in performance	Easy to pilot	Play a significant role
Solar hot water systems	77	93	93	85	77	56	86	59	62	67	70	80	89
Solar photovoltaic systems	65	92	95	85	73	51	85	55	58	64	67	79	89
Heat recovery (i.e. MVHR)	61	86	74	72	93	49	82	37	43	65	63	76	82
Air source heat pumps	50	80	67	45	52	36	80	33	33	43	42	67	68
Ground source heat pumps	44	37	71	52	82	17	74	34	25	38	42	35	70
Biomass systems	34	35	31	24	64	32	78	25	29	39	47	32	55
Renewable micro-combined heat and power	26	42	27	38	69	17	80	13	18	30	41	27	68
Micro-combined heat and power	19	75	50	42	80	25	83	29	30	43	48	39	70
Wind power systems	8	28	43	24	43	17	68	44	39	33	27	25	43
Fuel cells	8	50	40	47	70	17	79	19	23	33	40	26	57
Absorption heat pumps	6	69	60	38	67	8	78	28	30	44	42	53	68
Small-scale hydroelectric systems	5	20	50	18	45	9	77	24	32	44	47	16	33

Figure 39 Percentage of respondents that reply positively against each category. A graduated colour scale has been applied down each column.

Figure 39 clearly shows that the technologies which are used most, located at the top of the figure, have the largest number of green responses. This is particularly true for the solar based systems which score highly against all of the categories with perhaps the exception of the ease of which respondents can secure planning permission. More yellow begins to appear in the next two technologies (MVHR and ASHP). However ease of installation, use and maintenance and ability to pilot remains green. Following the top four the distribution of the green, yellow and red becomes more confused. With this sample size it is difficult to draw any strong conclusions other than those technologies which are used most have more green and those which are used least have more red.

This would indicate that each of the innovation factors interrogated plays a role in a given LZC technology becoming a realised solution. However, this data does not prove causality. It is possible that respondents score familiar technologies highly and unfamiliar technologies less so resulting in technologies which are used by most developers scoring the highest.

It is interesting to look at the number of different technologies that individual respondents are using. Figure 40 shows the percentage of respondents that are using a particular number of technologies.

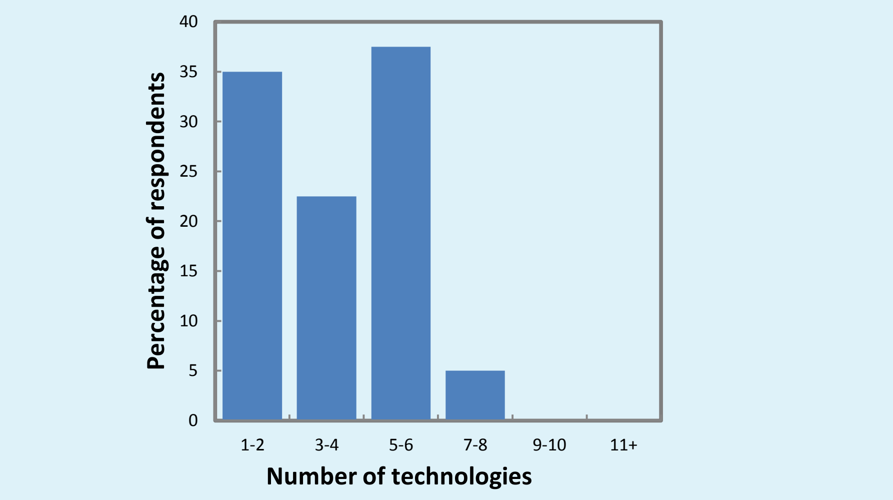


Figure 40 The percentage of respondents that are using a number of technologies (irrespective of site type and dwelling type).

Clearly respondents are using a range of different LZC technologies although almost a third rely on one or two technologies only. This distribution did not vary greatly between large and small developers. This variety perhaps reflects that different solutions are required locally for different developments or perhaps the uncertainty surrounding which technologies provide the most effective response to minimising carbon emission in a commercially viable manner.

There was a stark contrast between the variety of technologies used now and those that respondents expected to be the most important in the future. Figure 41 shows the percentage of respondents who indicated that they believed a particular technology will be the most important moving forward into the future.

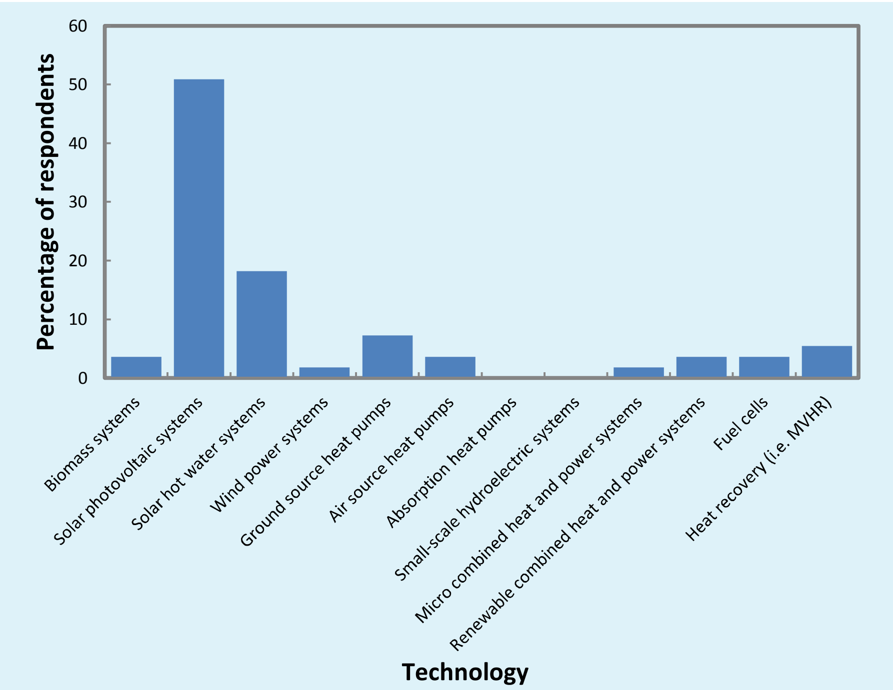


Figure 41 Percentage of respondents indicating which technology will be the most important moving into the future.

3.4. Summary

This survey of house builders suggests that solar based technologies (solar thermal and solar photovoltaic) are emerging as the dominant solution to lowering carbon emissions in new housing. Mechanical ventilation and heat recovery and air source heat pump systems are also popular choices.

There is evidence that the majority of respondents are using a range of low and zero carbon technologies to lower carbon emissions although almost a third are deploying only one or two types of technologies. When looking to the future, respondents identified the solar technologies as playing the largest role in lower carbon emissions. House builders are using a wider range of technologies on conversion and brownfield sites than on greenfield sites.

Technologies which are used score highly against a number of innovation factors including how easy they are to use, maintain and install and how compatible they are with house builders' design and build processes.

4 Phase 2: Lived-in user experiences

This section reports the interim findings of the second phase of the research. A series of interviews was conducted with occupants in their domestic setting. The in-depth interviews not only consisted of questions, but actually observed occupiers using the control panels to establish their practices and to compare them with the 'design' functionality of the technologies.

4.1 Developments and households

These interim findings report on ten interviews, conducted with five households, across three different developments. They include a mix of private owner occupiers and social renting tenants and greenfield and brownfield developments.

Development 1

Development 1 is a large multi-phase development in a small village. Some parts of the development are on rural brownfield sites and others on greenfield sites. The phase of the development used in this study comprises 26 houses which incorporate air source heat pump systems as the only source of domestic hot water and energy supply for the heating system. The air source heat pump system is supplemented by an electric immersion heater. The 26 houses are all private-owner occupiers.

Two households from Development 1 have taken part in this study.

Household 1a

Household 1a is a couple who both work full-time and own their current three bedroom end-terrace home. They have lived in the property for fourteen months. Their son spends three days a week at home when he is not at university. One of the parents works as an electrical engineer.

Household 1b

Household 1b is a recently retired couple who live in a semi-detached house and whose children have moved out. They have lived in the property for eleven months. They live the majority of the time in the UK but do spend time abroad at another property they own. Recently one of the couple, who has specialist knowledge relating to energy and energy supply, has returned to work two or three days a week where the person works as a senior plant engineer at a large industrial site.

Development 2

Development 2 is small development on a brownfield site of a three house terrace. The houses are being developed for a housing association as part of a larger local portfolio they manage in a village which is eight miles outside of a small city. The houses contain a solar thermal system which supplements a gas central heating system which also has an electric immersion heater.

Two households from Development 2 have taken part in this study.

Household 2a

Household 2a is a single parent family with one young child (nursery age). The family has strong ties to the local area. They have lived in the property for ten months. The young child spends the early part of each day at nursery. The property is a mid-terrace house owned and managed by a housing association and rented to the tenant. Four generations of the family live within walking distance of the development in properties managed by the same housing association. The housing association has begun a programme of retrofitting the same solar thermal technology to existing local stock, including that of household 2a's family.

Household 2b

Household 2b comprises two adults and two young teenagers who are social tenants in a three bedroom end-terrace property which is owned and managed by a housing association. The family has lived in the property for ten months. Both adults work, one full-time and the other part-time. Household 2b does have family ties to the local area but not as many as Household 2a.

Development 3

Development 3 is a large two-phase development including both houses and apartments on a greenfield site which is six miles outside of a large town. The development includes a mix of private and social dwellings and incorporates mechanical ventilation and heat recovery, solar thermal and solar photovoltaic systems. All three technologies are not necessarily installed in every dwelling.

One household from Development 3 has taken part in this study.

Household 3a

The family living in Household 3a is made up of a single parent and one young child (nursery age) who are social tenants. They have lived at the property for eight months. The property is a mid-terraced house owned and maintained by a housing association. Household 3a does not appear to have strong links to the local community and spends little time interacting with neighbours.

4.2 Emerging themes

Fieldwork is currently ongoing, however a number of themes are emerging strongly from the data. The themes are structured around three discernible phases: pre-occupation, everyday use and future expectations.

In each of the sections below a short narrative is given relating to each of the phases. After each narrative a series of indicative quotes from interviews are given to illustrate the issues raised. In some cases these quotes are in conflict with each other demonstrating the diversity, often opposing, views of occupants to LZC technologies. After each quote the household reference is given in parentheses.

Pre-Purchase

In each of the interviews the 'story' relating to how and why the occupants move into their current home was explored. From this, two linked themes have emerged. One relates to a lack of awareness by the occupants of the technology that is fitted in the dwelling. Also incorporated in this theme is the lack of importance that most occupants placed on the environmental performance of their homes in the purchasing decision. The other theme is related to the type of information that is supplied prior to the decision to occupy the dwelling mainly though the marketing process for owner occupiers and through the housing officer for social tenants. Table 1 presents the themes with a series of indicative quotes that illuminate each theme.

Table 1
The emerging themes in the pre-occupation phase

Theme	Supporting quotes
Awareness In all the cases the occupiers had far more important reasons for moving into a particular dwelling other than the environmental performance of the home. In many cases occupants have low levels of awareness of the technology that is installed. In some cases occupants only realised that a LZC technology was installed after they had moved into their home.	*"...it was a bonus when we discovered that the house did have the air source heat pump... but we weren't looking for that to start with. We were just looking at a house to move into."* (1a)
	"...we were looking to move back into the village. We had lived here a short while ago; about five or six years ago and we moved away; didn't like where we were, so wanted to move back to the village. So it was a [village] thing really, just to get back to the location." (1b)
	"It was only – I think even on the second occasion, when I walked out my garden and see this box, this magic box sitting out there and I thought, oh, what's that? And then they then said, "Oh, well you've got whatever it is."" (1b)
	"[About the technology] No, it was only on the day that we got the house, really. We didn't know anything about it up 'til then." (2b)
Appropriate information: support for purchase When occupants were aware of the LZC technologies installed in their homes they felt that there was a lack of appropriate information available to them at the point of sale or, in the case of social housing, rental. This lack of information includes both marketing literature and knowledge of sales staff.	*"I'm surprised that there isn't a document or a – I'm not saying a glossy brochure, but a document that says "This is what system – this is how it works generally.""* (1b)
	"...if you look at buying a car, I mean, they're go into quite a reasonable amount of depth when you buy a car, you know, even – or, I mean, I had Volkswagens and, you know, "Our paint is water based and it's," you know, and so on, and all the, you know, 95% of the parts can be recycled. And with this it's like a – just like a paper pamphlet, you know, and doesn't really give a lot away." (1b)
	"No one's explained anything. It's just a case of there it is, that's what you've got, it'll save you money in winter." (3a)

Everyday use

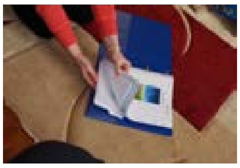
When discussing the day-to-day interactions with, or concerns regarding, the technologies, several themes emerged – cost, routines in practice, support for practice and workarounds. Table 2 describes each of these themes and provides supporting quotes.

Table 2
The emerging themes in the everyday use phase

Theme	Supporting quotes
Cost Occupier concern over the cost of gas and/or electricity appeared in each interview. Typically, occupants were unsure precisely how much energy they consumed but were more aware of how much their bills were. There was a high degree of uncertainty as to whether or not the LZC technology saved money. The uncertainty came from many sources, particularly estimated bills and difficulty in benchmarking energy bills against their previous homes which were often very different in size and overall environmental performance.	*"...the heating bills and it's difficult to tell, it's still quite early days, but they're certainly not any more than we were paying before."* (1a)
	"We've just taken a reading and when we moved into the house... the electricity suppliers have already been chosen [we] didn't take any notice of it for a month or two. And we suddenly got a notification through saying... something like "Your bill from the 1st October or 31st October will be 29 pence per kilowatt hour," and I thought, well that sounds a lot... So I rang up [the supplier] and I said, you know, "What is our current charge?"... and they said it was an eco-tariff... But what they were saying was that it was all to do with the carbon footprint and, you know, I got this sort of spin on the telephone, but the nub of it was can I go onto a cheaper tariff? And the answer was, yes, and providing we use over 900 kilowatts..." (1b)
	"...my gas and electricity bills compared to where I've lived in the past have been absolutely fantastic here." (2a)
	"...and the bills are, sort of, estimated, you know, that we'll use so much in a year..." (2b)

Table 2 continued

The emerging themes in the everyday use phase

Routines in practice This theme is used to capture the day-to-day interactions with the LZC technologies. These interactions occurred in both 'directions' with the occupants affecting the technology and the technology affecting the occupants. The key occupier-led interaction was uncertainty on how to correctly set the controls to deliver the desired performance. In contrast, the principal technology-led interaction was manifest in concern over noise coming from the technologies and how best to change behaviour (particularly water consumption) to benefit from the characteristics of specific LZC technologies. These two-way interactions materially alter the behaviour of households. In Case 2, in which the housing officer had instructed the tenants to use all their hot water in the morning, the presence of the LZC technology really shaped the routines within the household. In household 2a, with a stay at home parent, nearly all the hot water consumption occurred in the morning. In household 2b, where the adults were at work, consumption happened times other than the morning.	*"Well, we've benefited, in that the house is much warmer than we're used to. Oh, we have the facility to have it warm."* (1a)
	"...the noise side was a concern for me, mainly 'cause we sleep out the back and the neighbours with their systems are in the back." (1a)
	 *"'Cause this thing is running at – I mean, they're not screamingly noisy, but again, if you come from an industrial sort of environment it wouldn't affect you too much. If you was a ... a poet or something, it would probably drive you round the bend, you know?"* (1b)
	"...it's probably our fault, when you look at the temperature that's displayed, it'll be 21, 22, but to me it doesn't always feel like that. It feels cooler than that and I can run this heating and we'll just wind it up to about 26 or something to – so I'm not sure whether that's reading right or not. I had threatened to go and get, you know, sort of a greenhouse and start taking them temperatures and I haven't done anything about it." (1b)
	"...I'm finding I'm trying to do everything in the morning, sort of, especially with little 'un, like her bath and that 'cause nothing worse in the evening when it's cold you have a, sort of, lukewarm bath." (2a)
	"...you've got enough water and stuff to do whatever; to wash up dishes, and if we haven't, then we just put it on sort of an hour's function just to come on the timer and within ten, 20 minutes, or ten minutes really, you've got enough water again." (2b)
	"We have got an immersion, yeah, which we've never use... Well, we put it on the other day then we turned it off again because we didn't need it." (2b)
	"It was only sort of the end of the summer... time when it sort of was getting a bit chillier and you used longer showers and whatever. ... we didn't really think until one day I said, "Oh, we've got no hot water." (2b) 
	" [when talking about the housing associations instructions to "do everything in the morning"]... but shower wise – actually, I shower at night, but there you go." (2b)
Appropriate information: support for practice The theme of a lack of appropriate information continues into the everyday use phase. Typically occupants do not understand the technology in their homes and how to maximise the benefits from them. The written literature supplied to occupants is often not at an appropriate level. It is worth noting that this level varies greatly from one household to another. In one extreme example an occupant had requested a wiring diagram for the technology (1a) and in another it was clear the user manual was written in far too technical format for the occupant to understand (3a). In addition to the information provided by the house builder or housing association there is the feedback the occupants receive directly from the technology. In many cases the occupants were unsure what the technology was doing and if it was working as it should.	*"But what I don't like about the system is that there's no visibility of when an immersion heater cuts in."* (1b)
	"I don't understand it fully, I have to admit [laughs], and I didn't read the information, you know, I was told by housing association, "Do everything in the morning, you're covered" (2a)
	 *"Idiot proof information would be grand [laughs]. I like things very simplified. I don't like – you know, I've learnt from my dad telling me off enough times that I don't touch something that I don't know what I'm doing."* (2a)
	"...there is like a sort of guide panel thing that just says, you know, what it should look like ... if there's a problem it would like this and have a little red indicator... on the actual unit in the airing cupboard." (2b)
	"that's what I've got the manual for, but to me it's written for somebody who understands it already." (3a) 
	"... I don't know whether that's the temperature of the water or if that's the temperature of outside or inside, I don't know. I don't know." (3a)
	 *"There are settings you can set on it, but how you do it I have no idea [laughs]."* (3a)

Future expectations

Two themes have emerged in the future expectations section. The first, recommendations, is concerned with whether or not occupants have or would recommend the LZC technology they have to a friend or family member. It also includes if their current experience of LZC technologies would make them more or less likely to consider this an important factor in choosing a property in the future. The second, feedback loops, is around the lack of feedback sought so far from both house builders and housing associations on the performance of the home and technologies installed within it. Table 3 describes each of these themes and provides supporting quotes.

Table 3
The emerging themes in the future purchase phase

Recommendations This theme relates to if an occupant would recommend the technology to a friend or family member and if their experience of LZC technologies in their current home has affected their priorities in looking for a home in the future. There were a diverse range of opinions about the desirability of LZC technologies which they would convey to others. Those occupiers in a better position to take full advantage of the 'as designed' benefits of the LZC technologies, not surprisingly, were more positive. For example, in Development 2, the household which had an adult present in the home all day (2a) could make maximise use of the energy output of the solar thermal system, compared to the neighbouring household which was out at work during the day (2b).	*"I certainly wouldn't put anybody off and I've mentioned the fact to several people that we've got an air source heat pump, and they've shown an interest."* (1a)
	[about ASHP] *"So, no, I think, to answer your question, I think it's not a system that I would promote if I was looking like that."* (1b)
	[about solar thermal] *"I tell them if they can afford to do it go ahead and do it most definitely, most definitely." (2a)*
	[about solar thermal] *"Yes, I would recommend it and if people could get it installed then, yeah, great."* (2b)
Feedback loops Occupants have a wealth of information and ideas relating to the technology installed in their homes. The households, however, felt that there was a lack of feedback mechanisms to capture their experiences of LZC technologies to enhance future housing designs and marketing approaches.	[about ASHP] *"If it was me doing it from choice and I was privately buying it, I would have wanted then to have incorporated within the garage at the side of the house somewhere."* (1b)
	"I think it would be good if they'd done it with electric as well." (3a)

Appendix A – Summary of responses to the survey

The following appendix gives all of the responses collected to the survey. As the data is given question by question, all responses are included in the data set. So it is important to note that Appendix A contains all of the responses received (even if the respondent did not complete the survey) and the data in the main body of the report contains only the responses from respondents that completed the whole survey.

Appendix B provides more details on how the data in the main body of the report was treated.

Who responded?

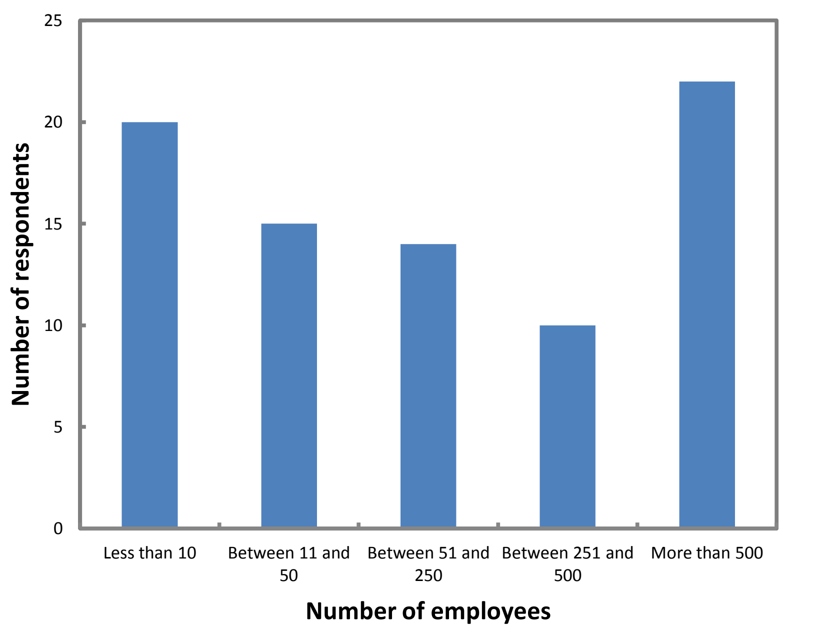
Participants were asked questions relating to their roles, experience and organisations.

Question 1 How many people does the company you work for employ?

The respondents came from a range of company sizes with a concentration under 10 and over 500 employees.

Number of employees	Frequency
Less than 10	20
Between 11 and 50	15
Between 51 and 250	14
Between 251 and 500	10
More than 500	22

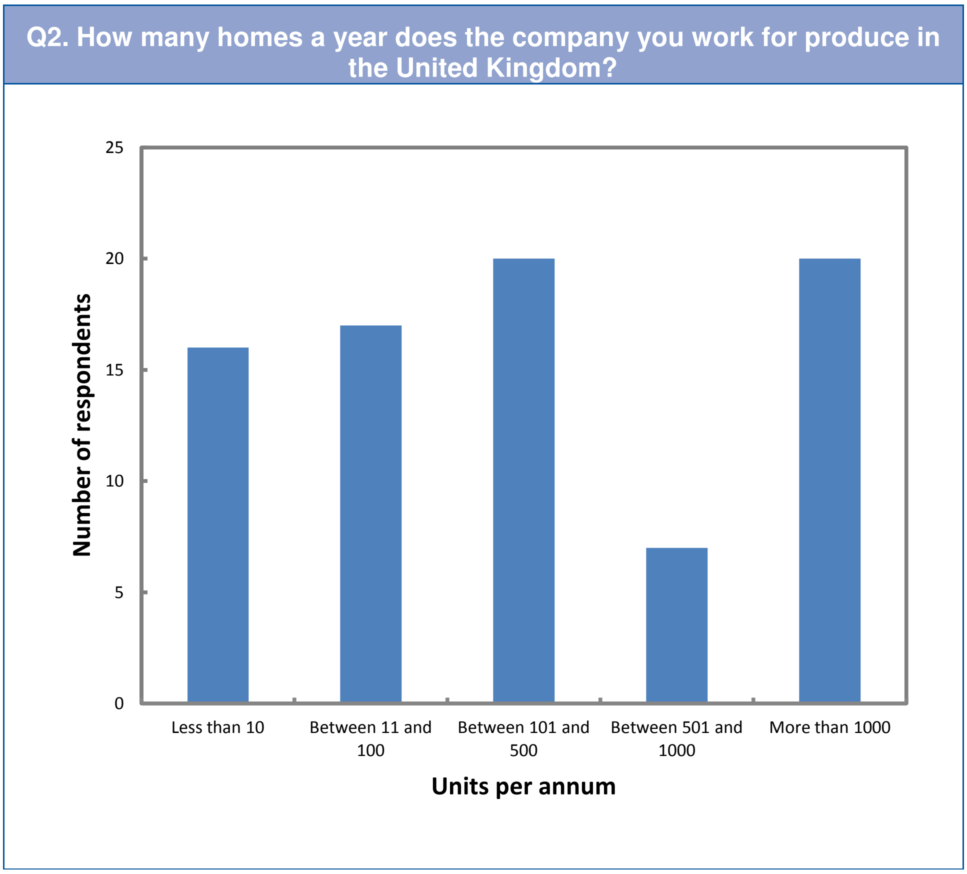
Q1. How many people does the company you work for employ?



Question 2 How many homes a year does the company you work for produce in the United Kingdom?

The sample set is evenly distributed with respect to units produced per year.

Units per year	Frequency
Less than 10	16
Between 11 and 100	17
Between 101 and 500	20
Between 501 and 1000	7
More than 1000	20

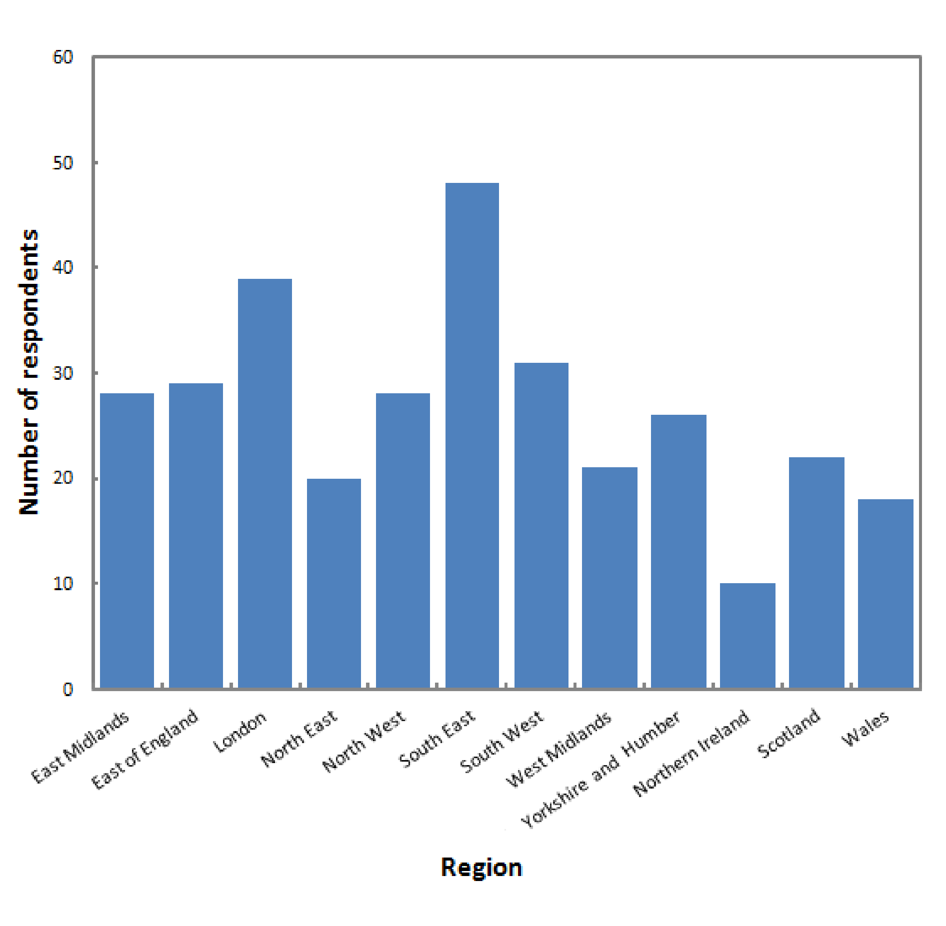


Question 3 In which regions does the company you work for produce homes?

The sample set covered all of the UK, with an emphasis on the South East.

Region	Frequency	Percentage of respondents active in this region
East Midlands	28	36
East of England	29	37
London	39	50
North East	20	26
North West	28	36
South East	48	62
South West	31	40
West Midlands	21	27
Yorkshire and Humber	26	33
Northern Ireland	10	13
Scotland	22	28
Wales	18	23

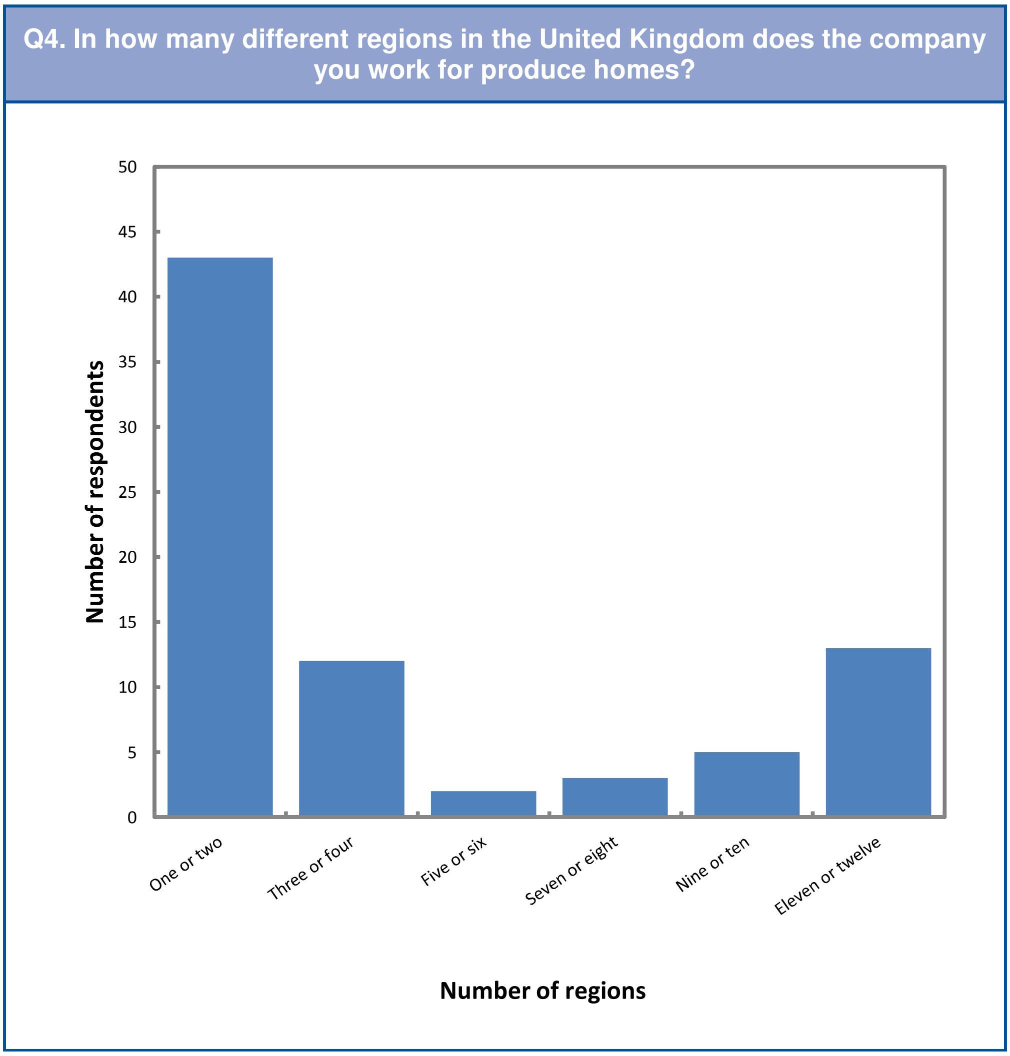
Q3. In which regions does the company you work for produce homes in?



Question 4 In how many different regions in the United Kingdom does the company you work for produce homes?

Participants tended to come from companies that worked in a small geographical area (one or two regions) or companies that had a national coverage (eleven or twelve regions).

Number of regions	Frequency
One or two	43
Three or four	12
Five or six	2
Seven or eight	3
Nine or ten	5
Eleven or twelve	13

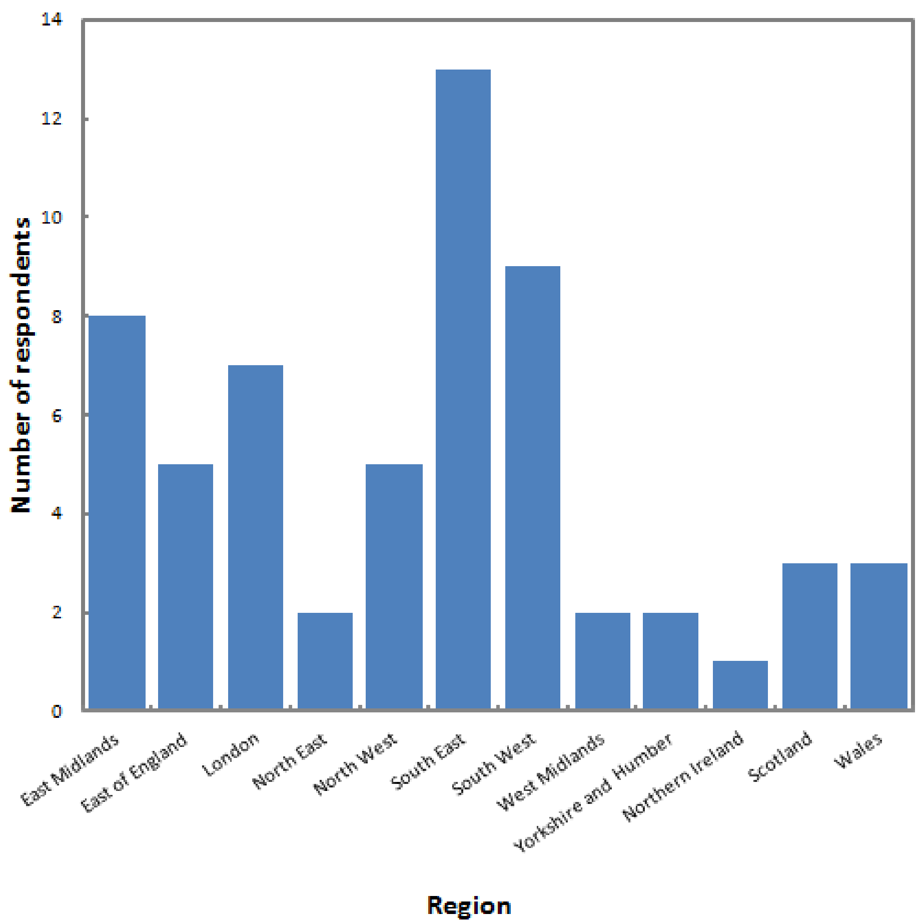


Question 5 In which region do you work?

The participants are from all parts of the UK, with an emphasis on the south-east.

Region	Frequency
East Midlands	8
East of England	5
London	7
North East	2
North West	5
South East	13
South West	9
West Midlands	2
Yorkshire and Humber	2
Northern Ireland	1
Scotland	3
Wales	3

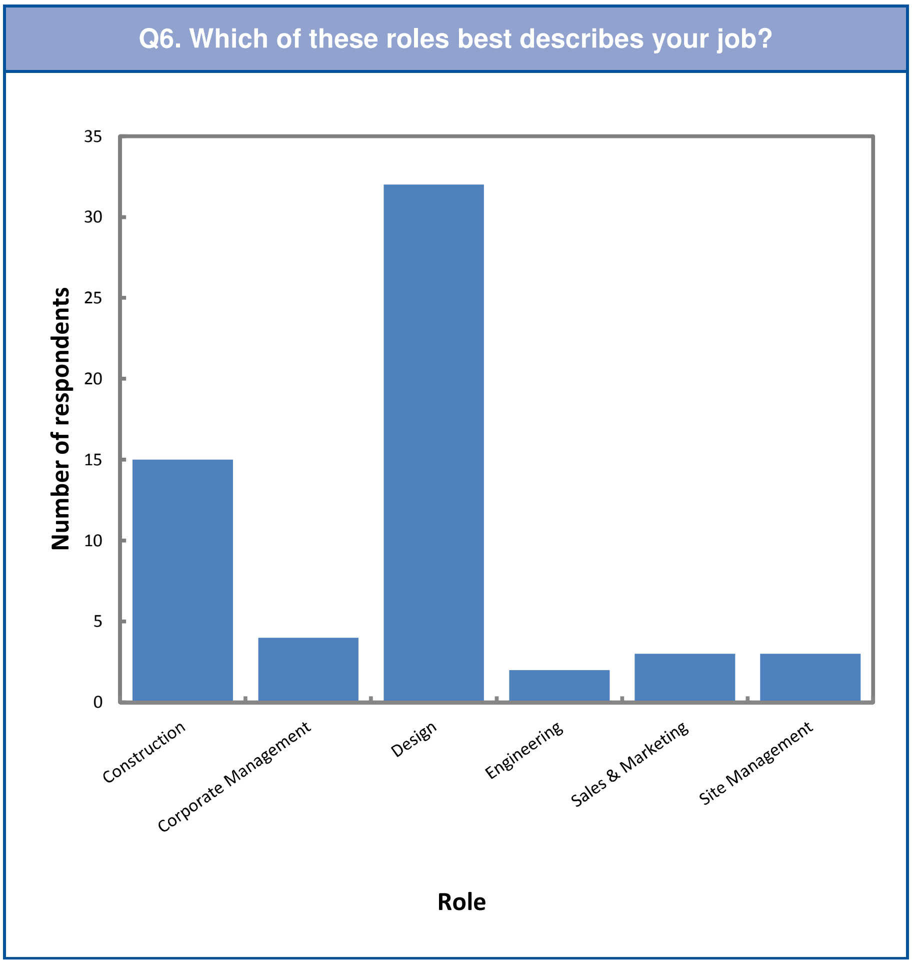
Q5. In which region do you work?



Question 6 Which of these roles best describes your job?

The majority of the participants have design or construction roles. There were also 25 participants that identified with 'other.'

Role	Frequency
Construction	15
Corporate Management	4
Design	32
Engineering	2
Sales & Marketing	3
Site Management	3

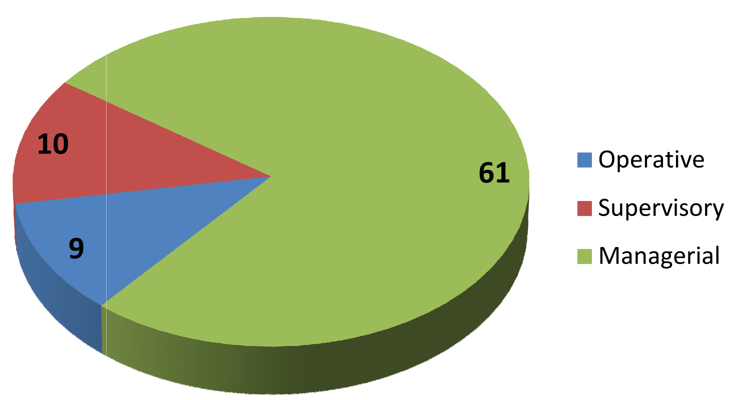


Question 7 Which level best describes your job?

The sample set covered all of the UK, with an emphasis on the South East.

Level	Frequency
Operative	9
Supervisory	10
Managerial	61

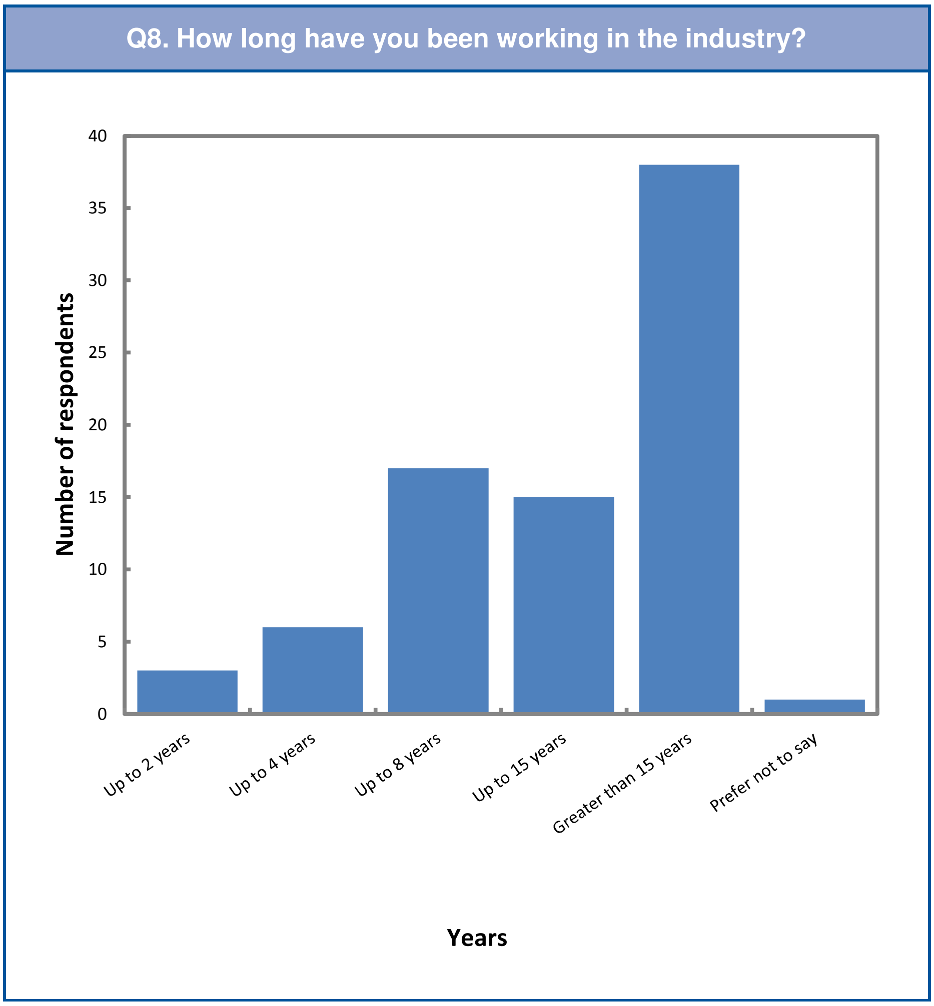
Q7. Which Level best describes your job?



Question 8 How long have you been working in the industry?

Participants tended to have been working in the industry for over 4 years, with the greatest number having worked in the industry for over 15 years.

Length of time in the industry	Frequency
Up to 2 years	3
Up to 4 years	6
Up to 8 years	17
Up to 15 years	15
Greater than 15 years	38
Prefer not to say	1

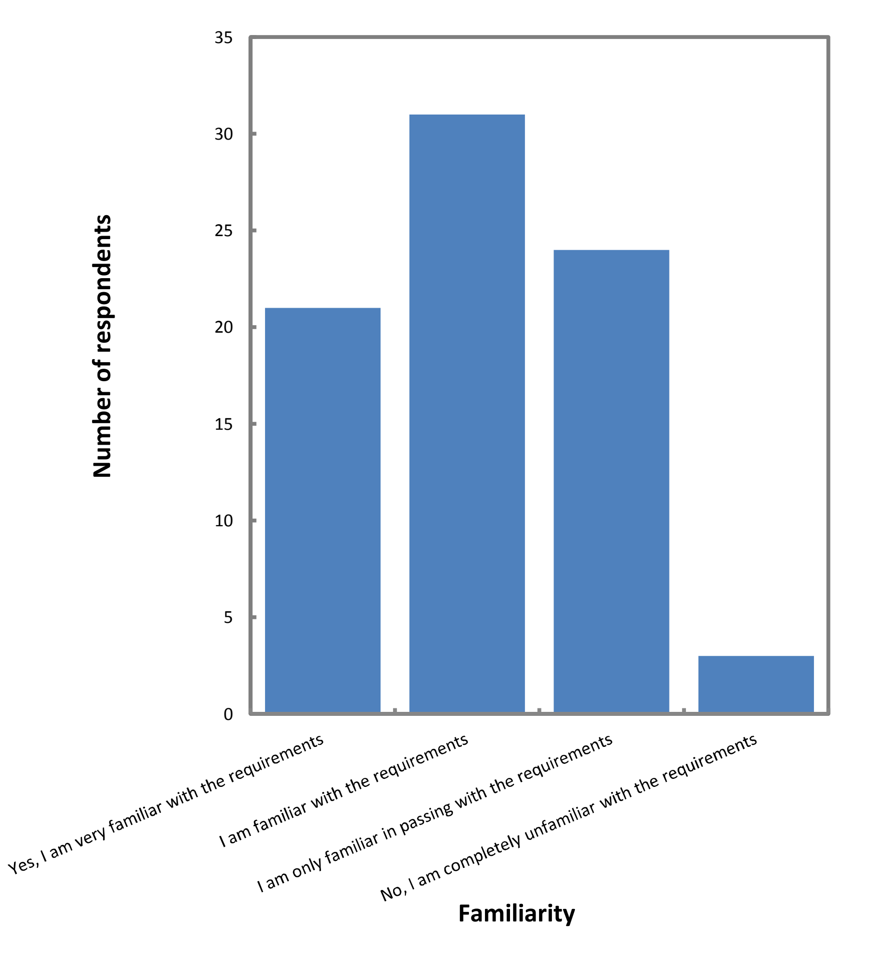


Question 9 How well do you understand what is required to work towards zero carbon in 2016?

Most participants indicate that they are either very familiar or familiar with the requirements. However, around one third are only familiar in passing and 3 were completely unfamiliar.

How well do you understand what is required to work towards zero carbon in 2016?	Frequency
Yes, I am very familiar with the requirements	21
I am familiar with the requirements	31
I am only familiar in passing with the requirements	24
No, I am completely unfamiliar with the requirements	3

Q9. How well do you understand what is required to work towards zero carbon in 2016?



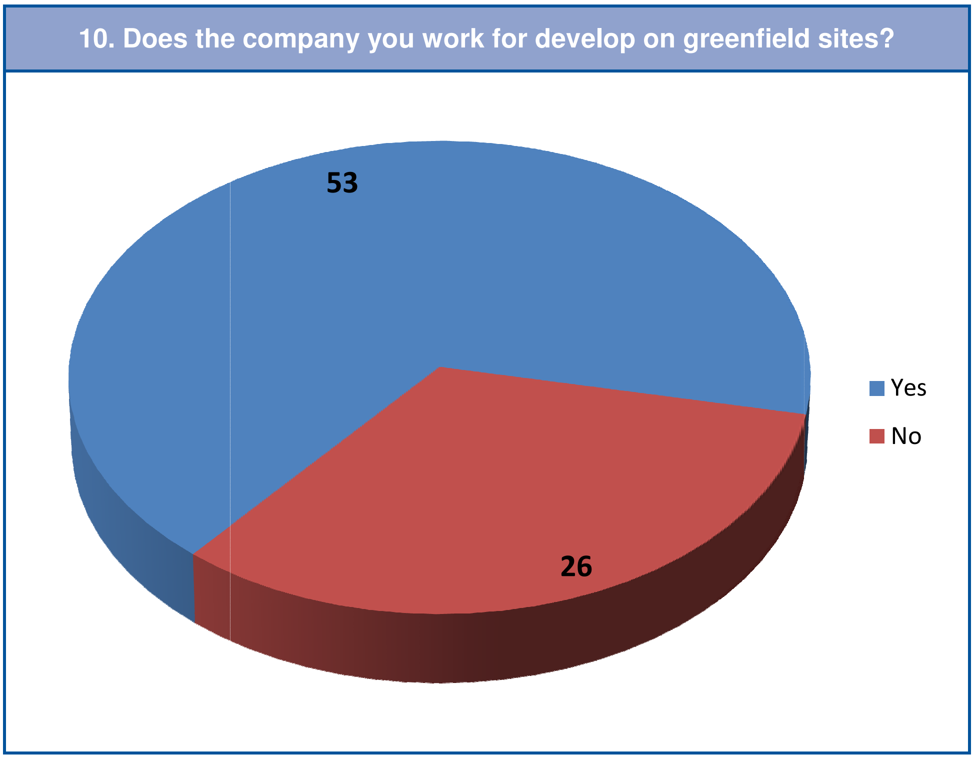
Which technologies?

Participants were asked to identify which site types they developed and, for each site type, what unit types they developed. Further, for each site type the range of technologies used for each unit type were identified.

Question 10 Does the company you work for develop on greenfield sites?

The sample set covered all of the UK, with an emphasis on the South East.

Does the company you work for develop on greenfield sites?	Frequency
Yes	53
No	26

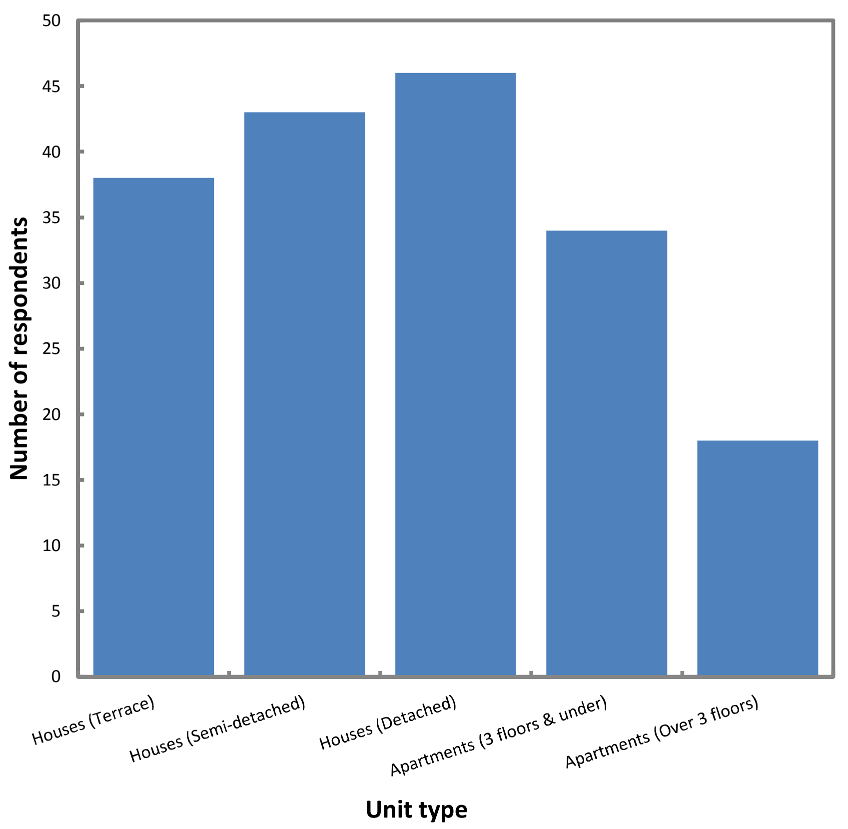


Question 11 Which house types does the company you work for develop on greenfield sites?

Participants tended to come from companies that worked in a small geographical area (one or two regions) or companies that had a national coverage (eleven or twelve regions).

Which home types does the company you work for develop on greenfield sites?	Frequency
Houses (Terrace)	38
Houses (Semi-detached)	43
Houses (Detached)	46
Apartments (3 floors & under)	34
Apartments (Over 3 floors)	18

Q11. Which home types does the company you work for develop on greenfield sites?



Question 12(a) Which low and zero carbon technologies does your company use on greenfield sites?

Some technologies, particularly those solar-based, are used significantly more than others.

Technology	For housing on GREENFIELD sites please indicate which low or zero carbon technology your company is using.				
	House			Apartment	
	Terrace	Semi	Detached	3 floors & under	Above 3 floors
Biomass systems	3	5	10	5	6
Solar photovoltaic systems	21	23	28	19	13
Solar hot water systems	20	24	27	15	7
Wind power systems	1	1	2	1	1
GSHP	9	8	14	4	3
Air source heat pumps	15	18	16	10	5
Absorption heat pumps	0	0	0	0	0
Small-scale hydroelectric	0	0	0	0	0
MCHP	1	1	2	1	1
r-MCHP	1	2	3	4	4
Fuel cells	1	0	0	0	0
Heat recovery (i.e. MVHR)	17	18	20	17	12

Question 12(b) Which low and zero carbon technologies does your company use on greenfield sites?

In order to more fairly compare the use of each LZC technology on greenfield sites the data in Question 12(a) is recast as a percentage of respondents using this technology on a given unit type that build that unit type. For example, if 20 out of 25 respondents who build terrace houses on greenfield sites use a particular LZC technology this would appear as 80% below.

The following is a summary of the data found on the next page. As this research adopts a purposive sampling strategy these statements, as with other observations of the data, apply to the sample set only. They are not intended as generalisations about the sector:

- Biomass is not a popular choice across any of the unit types but there are more examples of its use in detached houses
- Solar photovoltaics (PV) systems are one of the most popular. PV was deployed in detached houses more than other house types
- Solar thermal systems are one of the most popular. There are more examples of use in houses than apartments. Solar thermal is deployed in detached houses more than semi-detached and in semi-detached more than terraced houses.
- Wind power systems are unpopular with very little usage across the unit types.
- Ground source heat pumps are moderately popular. They are used more in houses than apartments and more so in detached houses than semi-detached or terraced
- Air source heat pumps are moderately popular. Use is higher in houses than apartments. Use was spread evenly across the different house unit types.
- Absorption heat pumps are not used
- Small-scale hydroelectric systems are not used
- Micro-combined heat and power (MCHP) systems are not a popular choice
- Renewable-combined heat and power systems are not a popular choice. They are used more than MCHP systems and are more popular in detached homes and apartments than in semi-detached and terraced homes
- Fuel cells are not popular
- Mechanical ventilation and heat recovery systems (MVHR) are a popular choice particularly in apartment buildings

Question 12(b) Which low and zero carbon technologies does your company use on greenfield sites?

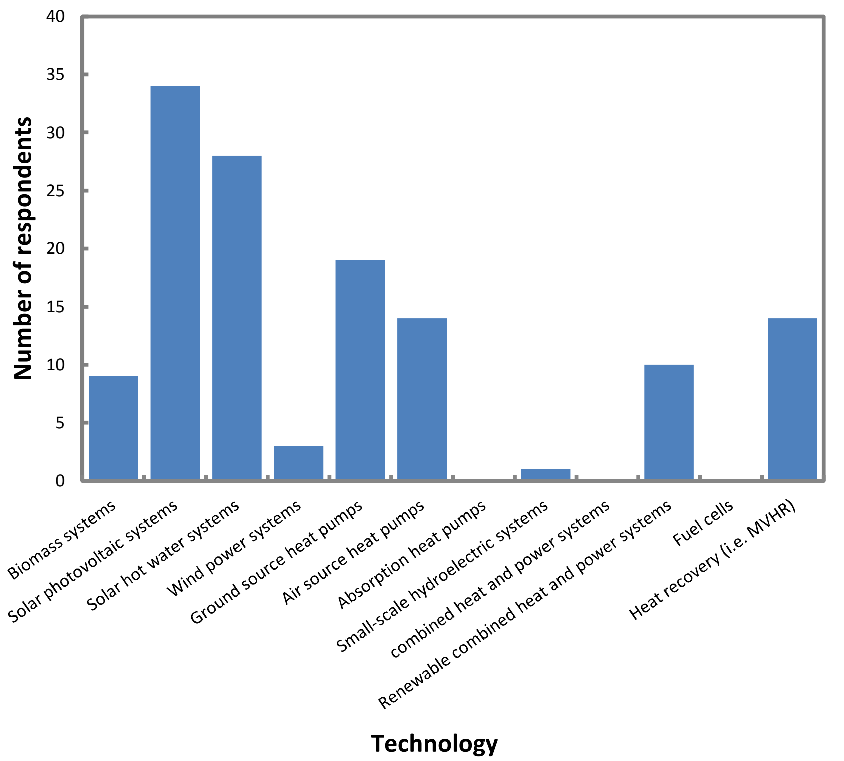
Technology	What percentage of respondents that build a particular unit type on greenfield sites use this technology?				
	House			Apartment	
	Terrace	Semi	Detached	3 floors & under	Above 3 floors
Biomass systems	8	12	22	15	33
Solar photovoltaic systems	55	53	61	56	72
Solar hot water systems	53	56	59	44	39
Wind power systems	3	2	4	3	6
Ground source heat pumps	24	19	30	12	17
Air source heat pumps	39	42	35	29	28
Absorption heat pumps	0	0	0	0	0
Small-scale hydroelectric systems	0	0	0	0	0
MCHP	3	2	4	3	6
r-MCHP	3	5	7	12	22
Fuel cells	3	0	0	0	0
Heat recovery (i.e. MVHR)	45	42	43	50	67

Question 13 Which three technologies do you think are the most important for greenfield sites?

The two solar technologies of PV and solar thermal are identified as being the most important for greenfield sites. There are a number of technologies not expected to be important such as wind powered systems, absorption heat pumps, small-scale hydroelectric systems, MCHP systems and fuel cells.

Technology	1st choice	2nd choice	3rd choice	Total
Biomass systems	4	1	4	9
Solar photovoltaic systems	17	10	7	34
Solar hot water systems	11	13	4	28
Wind power systems	0	2	1	3
Ground source heat pumps	4	6	9	19
Air source heat pumps	3	4	7	14
Absorption heat pumps	0	0	0	0
Small-scale hydroelectric systems	0	0	1	1
MCHP	0	0	0	0
r-MCHP	4	3	3	10
Fuel cells	0	0	0	0
Heat recovery (i.e. MVHR)	3	6	5	14

Q13. Which three technologies do you think are the most important for greenfield sites?

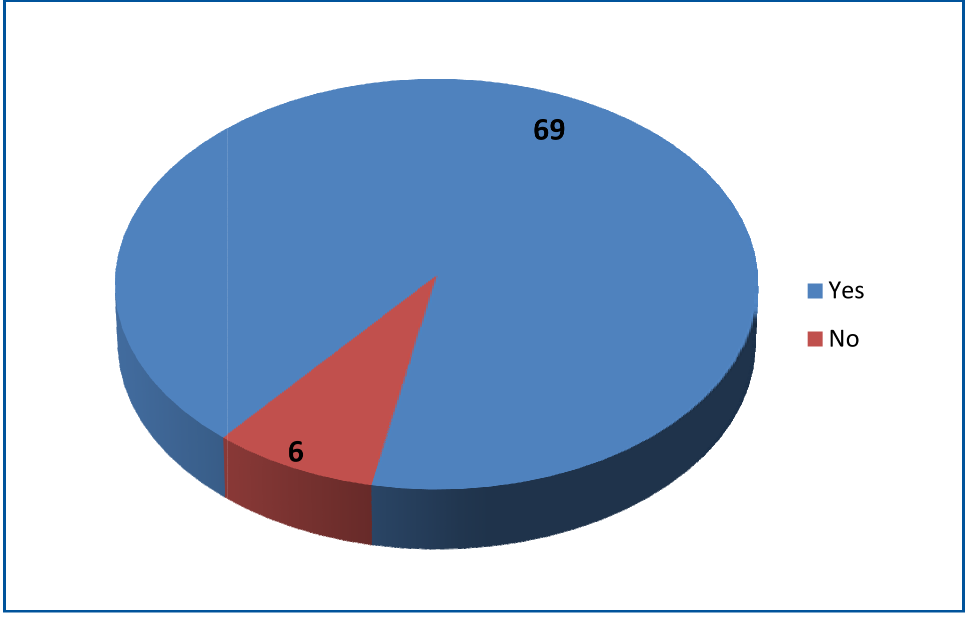


Question 14 Does the company you work for develop on brownfield sites?

The majority of the respondents develop on brownfield sites.

Does the company you work for develop on brownfield sites?	Frequency
Yes	69
No	6

Q14. Does the company you work for develop on brownfield sites?

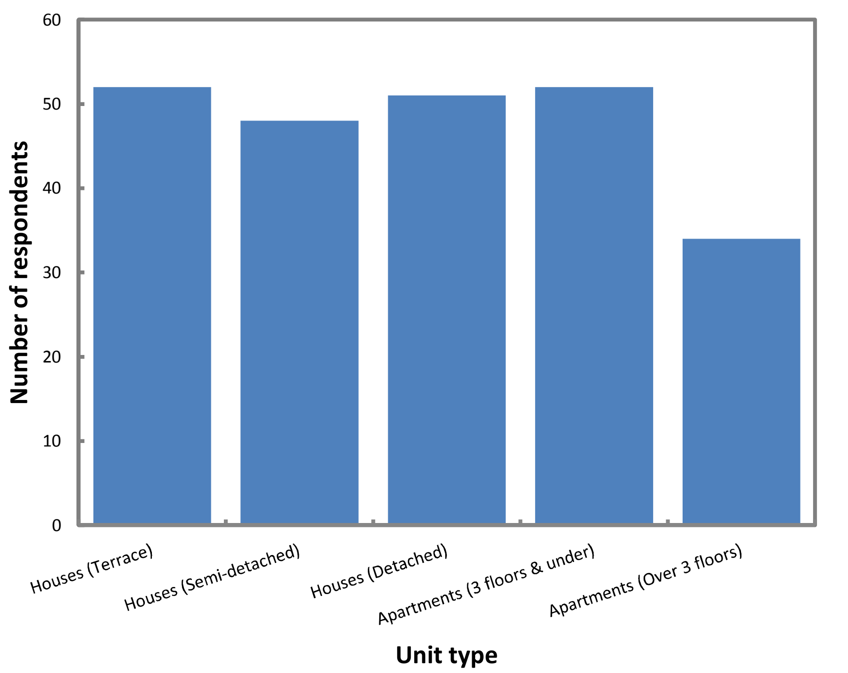


Question 15 Which house types does the company you work for develop on brownfield sites?

Less respondents build apartment buildings three floors and over than the other types of unit.

What housing types does the company you work for build on BROWNFIELD sites?	Frequency
Houses (Terrace)	52
Houses (Semi-detached)	48
Houses (Detached)	51
Apartments (3 floors & under)	52
Apartments (Over 3 floors)	34

Q15. Which house types does the company you work for develop on brownfield sites?



Question 16(a) Which low and zero carbon technologies does your company use on brownfield sites?

The sample set covered all of the UK, with an emphasis on the South East.

Technology	Which low and zero carbon technologies does your company use on brownfield sites?				
	House			Apartment	
	Terrace	Semi	Detached	3 floors & under	above 3 floors
Biomass systems	5	5	6	6	12
Solar photovoltaic systems	34	35	34	30	22
Solar hot water systems	40	38	38	24	13
Wind power systems	1	1	4	2	1
GSHP	7	7	14	9	6
Air source heat pumps	18	18	21	21	12
Absorption heat pumps	0	0	1	1	1
Small-scale hydroelectric	1	1	1	1	1
MCHP	4	4	4	8	10
r-MCHP	4	4	4	12	11
Fuel cells	0	0	1	2	2
Heat recovery (i.e. MVHR)	27	27	29	31	24

Question 16(b) Which low and zero carbon technologies does your company use on brownfield sites?

In order to more fairly compare the use of each LZC technology on brownfield sites the data in Question 16(a) is recast as a percentage of respondents using this technology on a given unit type that build that unit type.

The following is a summary of the data found below:

- Biomass was not a popular choice across all unit types apart from apartment buildings of three floors and over
- PV systems are one of the most popular
- Solar thermal systems are one of the most popular. There are fewer examples of solar thermal systems in apartment buildings
- Wind power systems are unpopular with very little usage across the unit types
- Ground source heat pumps are moderately popular. There are more examples of GSHP use in detached houses
- Air source heat pumps are moderately popular
- Absorption heat pumps are not popular
- Small-scale hydroelectric systems are not popular
- Micro-combined heat and power systems are not a popular choice. There are more examples of MCHP systems in apartments than houses
- Renewable-combined heat and power systems are not a popular choice. There are more examples of MCHP systems in apartments than houses.
- Fuel cells are not popular
- Mechanical ventilation and heat recovery systems (MVHR) are a popular choice particularly in apartments

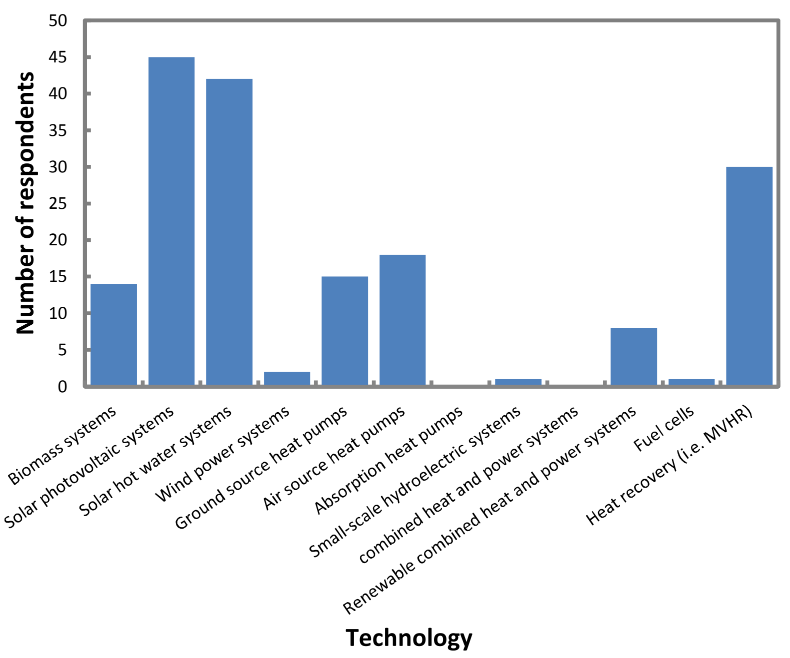
Technology	What percentage of respondents that build a particular unit type on brownfield sites use this technology?				
	House			Apartment	
	Terrace	Semi	Detached	3 floors & under	Above 3 floors
Biomass systems	10	10	12	12	35
Solar photovoltaic systems	65	73	67	58	65
Solar hot water systems	77	79	75	46	38
Wind power systems	2	2	8	4	3
GSHP	13	15	27	17	18
Air source heat pumps	35	38	41	40	35
Absorption heat pumps	0	0	2	2	3
Small-scale hydroelectric	2	2	2	2	3
MCHP	8	8	8	15	29
r-MCHP	8	8	8	23	32
Fuel cells	0	0	2	4	6
Heat recovery (i.e. MVHR)	52	56	57	60	71

Question 17 Which three technologies do you think are the most important for brownfield sites?

The two solar technologies of PV and solar thermal system are identified as being the most important for brownfield sites, followed closely by MVHR systems. There are a number of technologies not expected to be important, such as wind powered systems, absorption heat pumps, small-scale hydroelectric systems, MCHP systems and fuel cells.

Technology	1st choice	2nd choice	3rd choice	Total
Biomass systems	3	5	6	14
Solar photovoltaic systems	22	12	11	45
Solar hot water systems	20	17	5	42
Wind power systems	0	1	1	2
Ground source heat pumps	4	4	7	15
Air source heat pumps	5	5	8	18
Absorption heat pumps	0	0	0	0
Small-scale hydroelectric systems	0	0	1	1
MCHP	0	0	0	0
r-MCHP	1	3	4	8
Fuel cells	0	1	0	1
Heat recovery (i.e. MVHR)	4	13	13	30

Q17. Which three technologies do you think are the most important for brownfield sites?

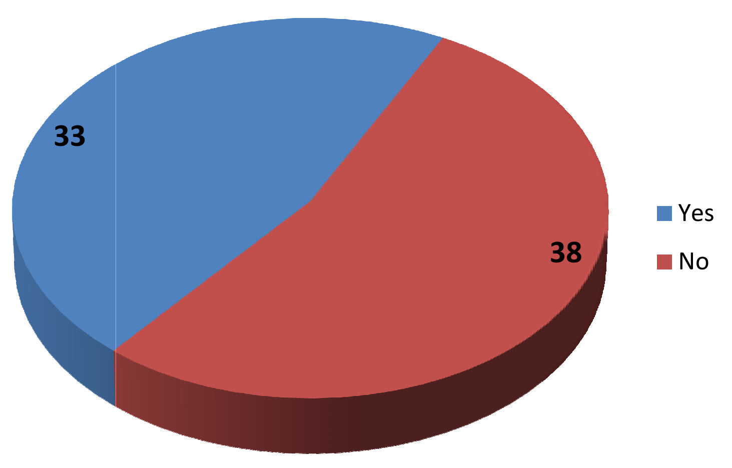


Question 18 Does the company you work for develop on conversion sites?

The majority of respondents do not convert existing buildings.

Does the company you work for develop on conversion sites?	Frequency
Yes	33
No	38

Q18. Does the company you work for develop on conversion sites?

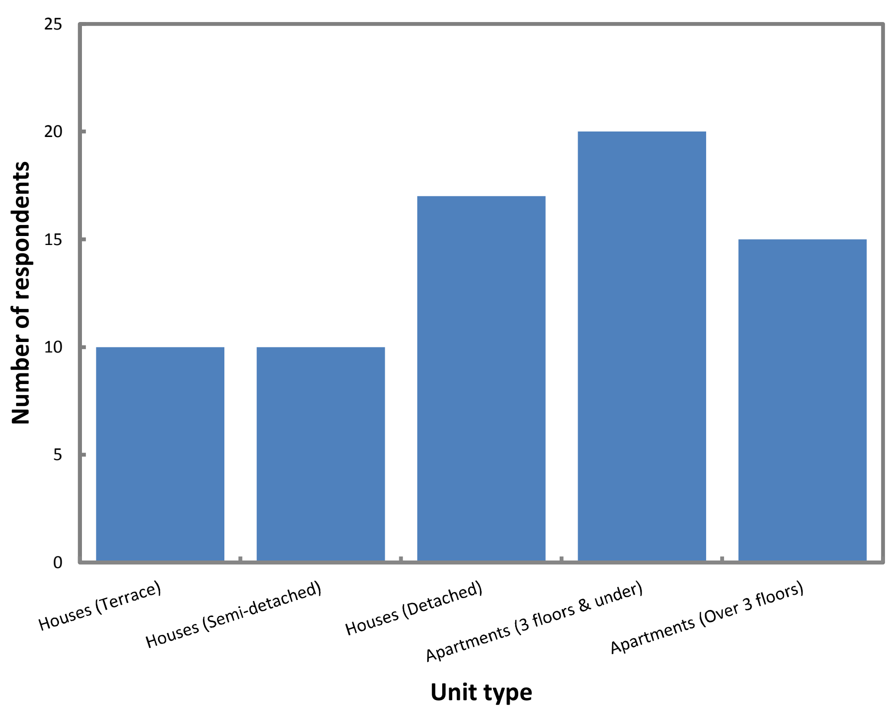


Question 19 Which housing types does the company you work for build on conversion sites?

The majority of respondents who are active in converting properties do so to detached houses or apartments.

Which housing types does the company you work for build on CONVERSION sites?	Frequency
Houses (Terrace)	10
Houses (Semi-detached)	10
Houses (Detached)	17
Apartments (3 floors & under)	20
Apartments (Over 3 floors)	15

Q19. Which housing types does the company you work for build on CONVERSION sites?



Question 20(a) Which low and zero carbon technologies does your company use on conversion sites?

Although there were fewer respondents developing on conversion sites, the same LZC technologies appear to be popular as for greenfield and brownfield sites.

Technology	Which low and zero carbon technologies does your company use on conversion sites?				
	House			Apartment	
	Terrace	Semi	Detached	3 floors & under	above 3 floors
Biomass systems	0	0	4	3	3
Solar photovoltaic systems	5	6	9	12	10
Solar hot water systems	7	9	13	11	5
Wind power systems	2	1	2	1	1
Ground source heat pumps	2	2	5	3	3
Air source heat pumps	2	2	4	7	7
Absorption heat pumps	1	1	1	2	1
Small-scale hydroelectric	0	0	1	0	0
MCHP	1	1	3	7	6
r-MCHP	2	2	3	5	5
Fuel cells	0	0	1	2	2
Heat recovery (i.e. MVHR)	5	5	7	13	10

Question 20(b) Which low and zero carbon technologies does your company use on conversion sites?

In order to more fairly compare the use of each LZC technology on conversion sites the data in Question 20(a) is recast as a percentage of respondents using this technology on a given unit type who build that unit type.

The following is a summary of the data below:

- Biomass systems are not a popular choice in smaller houses but are more popular in detached houses and apartments
- PV systems are one of the most popular
- Solar thermal systems are very popular. There are fewer examples of solar thermal systems in apartment buildings
- Wind power systems are more popular than on greenfield and brownfield sites
- Ground source heat pumps are moderately popular. There are more examples of GSHP use in detached houses
- Air source heat pumps are moderately popular
- Absorption heat pumps are not popular
- Small-scale hydroelectric systems are not popular
- Micro-combined heat and power systems are not a popular choice. There are more examples of MCHP systems in apartments than houses
- Renewable-combined heat and power systems are not a popular choice. There are more examples of MCHP systems in apartments than houses
- Fuel cells are not popular
- Mechanical ventilation and heat recovery systems (MVHR) are a popular choice particularly in apartments

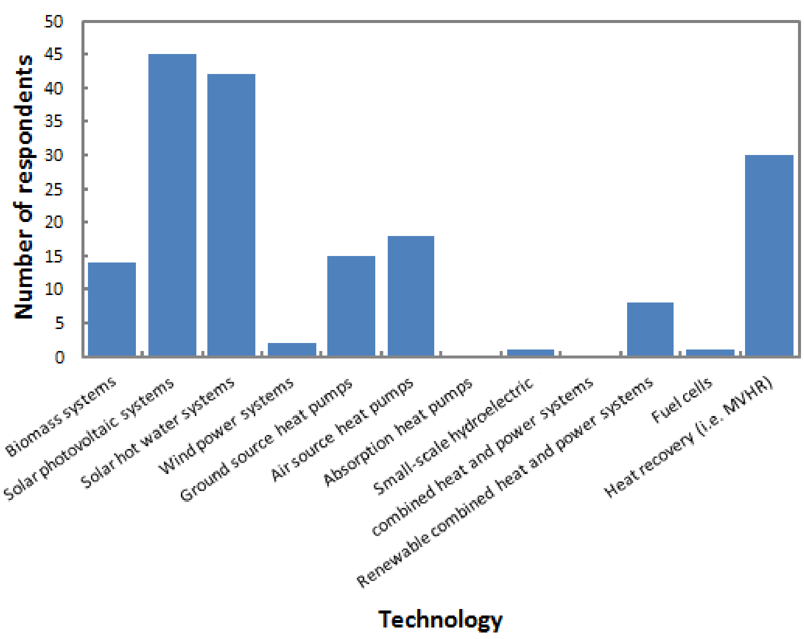
Technology	What percentage of respondents that build a particular unit type on conversion sites use this technology?				
	House			Apartment	
	Terrace	Semi	Detached	3 floors & under	above 3 floors
Biomass systems	0	0	24	15	20
Solar photovoltaic systems	50	60	53	60	67
Solar hot water systems	70	90	76	55	33
Wind power systems	20	10	12	5	7
Ground source heat pumps	20	20	29	15	20
Air source heat pumps	20	20	24	35	47
Absorption heat pumps	10	10	6	10	7
Small-scale hydroelectric	0	0	6	0	0
MCHP	10	10	18	35	40
r-MCHP	20	20	18	25	33
Fuel cells	0	0	6	10	13
Heat recovery (i.e. MVHR)	50	50	41	65	67

Question 21 Which technologies do you think are the most important for conversion sites?

The two solar technologies of PV and solar thermal are identified to be the most important for conversion sites followed closely by MVHR systems. There are a number of technologies not expected to be important, such as wind powered systems, absorption heat pumps, small-scale hydroelectric systems, MCHP systems and fuel cells.

Technology	1st choice	2nd choice	3rd choice	Total
Biomass systems	4	1	3	8
Solar photovoltaic systems	9	7	3	19
Solar hot water systems	4	9	7	20
Wind power systems	0	1	0	1
Ground source heat pumps	4	2	3	9
Air source heat pumps	1	3	3	7
Absorption heat pumps	0	0	0	0
Small-scale hydroelectric	0	0	0	0
MCHP	0	0	0	0
r-MCHP	2	0	3	5
Fuel cells	0	0	1	1
Heat recovery (i.e. MVHR)	6	4	3	13

Q21. Which three technologies do you think are the most important for conversion sites?



What factors?

Participants were asked questions relating to how they felt each technology performed relating to a series of innovation factors.

Question 22 On a scale of 1 to 5 please indicate how much you agree with the following statement. *"I believe this technology is easy to install."*

The two solar technologies are identified as being the easiest to install with MVHR, ASHP and biomass moderately easy to install.

Technology	1. Disagree	2. Somewhat disagree	3. Neither agree or disagree	4. Somewhat agree	5. Agree	Do not know
Biomass systems	8	20	15	5	10	8
Solar photovoltaic systems	1	4	3	13	46	0
Solar hot water systems	0	4	3	16	43	0
Wind power systems	10	20	12	6	6	12
Ground source heat pumps	7	27	7	8	12	5
Air source heat pumps	1	8	14	16	21	5
Absorption heat pumps	1	3	11	6	4	40
Small-scale hydroelectric	12	9	8	3	2	31
MCHP	4	6	9	16	8	23
r-MCHP	5	14	9	11	2	25
Fuel cells	5	3	10	6	1	41
Heat recovery (i.e. MVHR)	2	5	8	20	27	5

Question 23 On a scale of 1 to 5 please indicate how much you agree with the following statement. *"This technology is easy to use and maintain as evidenced by feedback from occupants."*

Solar technologies are identified as easy to use and maintain. For the majority of technologies most participants indicated 'Do not know'.

Technology	1. Disagree	2. Somewhat disagree	3. Neither agree or disagree	4. Somewhat agree	5. Agree	Do not know
Biomass systems	5	9	6	3	2	16
Solar photovoltaic systems	1	1	6	16	26	14
Solar hot water systems	0	3	4	16	27	13
Wind power systems	4	5	9	4	3	37
Ground source heat pumps	1	5	15	4	9	29
Air source heat pumps	2	7	15	15	4	19
Absorption heat pumps	1	1	13	2	1	43
Small-scale hydroelectric	2	1	11	2	1	45
MCHP	3	5	11	4	3	36
r-MCHP	5	7	11	2	2	35
Fuel cells	3	0	13	1	1	44
Heat recovery (i.e. MVHR)	3	5	12	17	9	18

Question 24 Please indicate for each of the technologies below if you believe that the inclusion of that technology would make a home more or less easy to sell.

Solar technologies are identified as making a property the most easy to sell.

Technology	Much easier to sell	Slightly easier to sell	Neither harder nor easier to sell	Slightly harder to sell	Much harder to sell	Do not know
Biomass systems	2	4	15	21	13	6
Solar photovoltaic systems	15	25	15	6	1	1
Solar hot water systems	15	27	13	7	0	1
Wind power systems	2	8	10	18	11	13
Ground source heat pumps	6	12	21	13	3	8
Air source heat pumps	5	11	22	15	3	7
Absorption heat pumps	2	3	14	6	2	35
Small-scale hydroelectric	0	3	10	7	7	34
MCHP	3	8	13	12	3	24
r-MCHP	4	7	10	14	4	23
Fuel cells	1	6	9	6	2	38
Heat recovery (i.e. MVHR)	7	17	26	7	2	5

Question 25 Please indicate if you believe that the inclusion of the technologies below would make it more, or less, easy to secure planning permission?

Solar technologies are identified as easier to secure planning permission. Wind powered systems are identified as making it difficult to secure planning permission.

Technology	Much easier	Slightly easier	Neither harder or easier	Slightly harder	Much harder	Do not know
Biomass systems	5	12	12	3	5	3
Solar photovoltaic systems	12	21	17	7	0	4
Solar hot water systems	12	22	18	6	0	4
Wind power systems	3	6	10	14	18	8
Ground source heat pumps	5	15	32	4	0	5
Air source heat pumps	3	14	25	11	1	7
Absorption heat pumps	3	9	12	4	0	32
Small-scale hydroelectric	2	5	11	8	5	29
MCHP	6	7	19	2	1	25
r-MCHP	7	10	12	5	0	26
Fuel cells	3	7	9	4	0	37
Heat recovery (i.e. MVHR)	7	14	30	1	0	8

Question 26 In terms of the total cost of including the technology per dwelling, please indicate for each of the technologies below if you believe that the inclusion of this technology today would make a home more, or less, expensive to build compared to a home built to 2006 Building Regulations?

All technologies are indicated as increasing the cost of producing a unit.

Technology	1. More expensive	2. Slightly more expensive	3. Neither more or less expensive	4. Slightly cheaper	5. Cheaper	6. Do not know
Biomass systems	42	9	4	1	0	4
Solar photovoltaic systems	42	14	1	2	0	2
Solar hot water systems	31	23	5	2	0	2
Wind power systems	41	12	1	1	0	7
Ground source heat pumps	45	10	1	1	0	4
Air source heat pumps	35	17	3	1	0	5
Absorption heat pumps	31	5	3	1	0	21
Small-scale hydroelectric	37	4	1	1	0	17
MCHP	36	7	1	1	0	16
r-MCHP	34	5	2	1	0	19
Fuel cells	33	6	1	0	0	21
Heat recovery (i.e. MVHR)	26	24	3	3	0	5

Question 27 For each of the technologies below have you noticed any trends in the total cost of including the technology per dwelling?

A number of respondents noticing a small decrease in the cost of solar based technologies.

Technology	1. Much cheaper	2. Slightly cheaper	3. No change in cost	4. Slightly more expensive	5. Much more expensive	6. Have not noticed	7. Do not know
Biomass systems	0	3	10	10	9	4	23
Solar photovoltaic systems	1	21	6	12	8	1	11
Solar hot water systems	2	22	4	13	5	2	11
Wind power systems	0	4	7	7	8	1	33
GSHP	0	5	8	8	11	2	26
ASHP	0	11	11	10	8	2	19
Absorption heat pumps	0	2	6	5	6	1	0
Small-scale hydroelectric	0	2	5	3	7	1	39
MCHP	0	5	3	7	5	1	42
r-MCHP	0	4	3	7	8	1	37
Fuel cells	0	3	4	5	5	2	37
MVHR	2	17	7	11	8	3	41

Question 28 Over the next five years, compared to today's prices, do you anticipate a change in the total cost of including each of these technologies per dwelling?

There is a general expectation that most technologies will fall in price in real terms.

Technology	1. Much cheaper	2. Slightly cheaper	3. Remain the same	4. Slightly more expensive	5. Much more expensive	6. Do not know
Biomass systems	3	22	13	6	2	14
Solar photovoltaic systems	13	33	3	5	3	5
Solar hot water systems	10	40	1	5	3	4
Wind power systems	2	18	16	7	2	18
Ground source heat pumps	6	24	12	8	2	11
Air source heat pumps	5	32	9	7	2	7
Absorption heat pumps	3	16	6	4	1	32
Small-scale hydroelectric	2	16	5	4	1	34
MCHP	6	24	5	4	2	21
r-MCHP	3	22	6	4	2	25
Fuel cells	4	16	6	3	2	31
Heat recovery (i.e. MVHR)	9	28	9	7	1	8

Question 29 Please indicate how much you agree with the following statement. *"We would have to change the way in which we DESIGN our homes a great deal to incorporate this technology."*

Solar based technologies are identified as being most compatible with current design approaches.

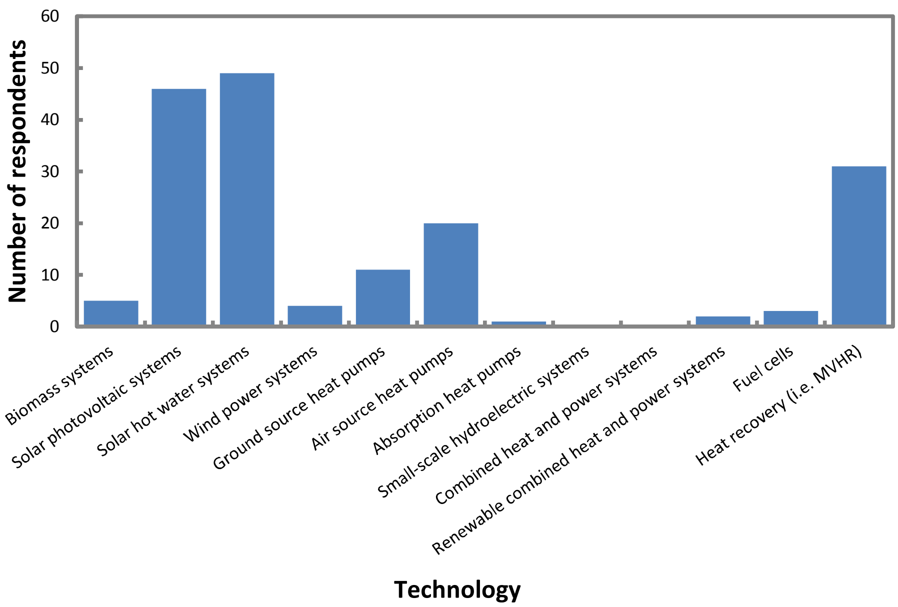
Technology	1. Disagree	2. Somewhat disagree	3. Neither agree or disagree	4. Somewhat agree	5. Agree	Do not know
Biomass systems	5	7	4	19	24	2
Solar photovoltaic systems	13	17	5	16	8	0
Solar hot water systems	16	17	6	14	8	0
Wind power systems	10	9	9	13	12	7
Ground source heat pumps	7	10	6	20	14	4
Air source heat pumps	4	12	10	21	10	3
Absorption heat pumps	2	6	5	10	8	30
Small-scale hydroelectric	1	5	6	10	10	29
MCHP	3	7	6	16	10	18
r-MCHP	1	3	5	16	11	24
Fuel cells	2	2	4	6	12	33
Heat recovery (i.e. MVHR)	7	11	12	18	11	1

Question 30 Which three technologies do you think are the MOST compatible with current designs?

The solar technologies are identified as being the most compatible with current design processes.

Technology	1st choice	2nd choice	3rd choice	Total
Biomass systems	3	1	1	5
Solar photovoltaic systems	25	14	7	46
Solar hot water systems	12	30	7	49
Wind power systems	1	0	3	4
Ground source heat pumps	2	5	4	11
Air source heat pumps	3	6	11	20
Absorption heat pumps	1	0	0	1
Small-scale hydroelectric	0	0	0	0
MCHP	0	0	0	0
r-MCHP	1	0	1	2
Fuel cells	0	0	3	3
Heat recovery (i.e. MVHR)	10	3	18	31

Q30. Which three technologies do you think are the MOST compatible with current designs?



Question 31 Please indicate how much you agree with the following statement. *"We would have to change the way in which we BUILD our homes a great deal to incorporate this technology."*

Solar based technologies are identified as being most compatible with current build processes.

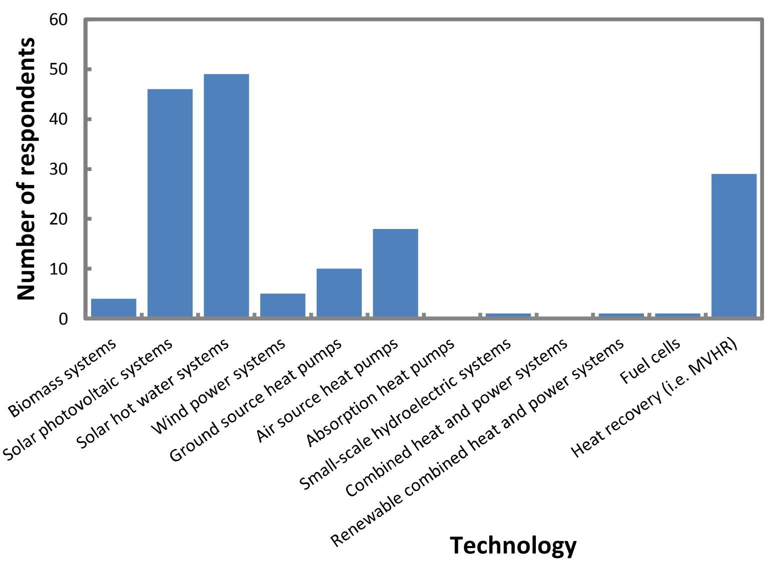
Technology	1. Disagree	2. Somewhat disagree	3. Neither agree or disagree	4. Somewhat agree	5. Agree	Do not know
Biomass systems	4	7	11	17	19	4
Solar photovoltaic systems	12	20	7	15	7	0
Solar hot water systems	13	19	10	13	6	0
Wind power systems	9	8	12	15	13	5
Ground source heat pumps	6	7	7	22	17	1
Air source heat pumps	5	10	14	21	7	5
Absorption heat pumps	3	5	7	8	8	30
Small-scale hydroelectric	3	6	6	9	11	27
MCHP	2	9	7	19	8	16
r-MCHP	1	5	5	15	13	22
Fuel cells	1	4	4	10	8	32
Heat recovery (i.e. MVHR)	11	12	8	17	12	1

Question 32 Which three technologies do you think are the MOST compatible with current building processes?

The solar technologies are identified as being the most compatible with current build processes.

Technology	1st choice	2nd choice	3rd choice	Total
Biomass systems	2	1	1	4
Solar photovoltaic systems	25	14	7	46
Solar hot water systems	13	27	9	49
Wind power systems	2	0	3	5
Ground source heat pumps	2	3	5	10
Air source heat pumps	3	3	12	18
Absorption heat pumps	0	0	0	0
Small-scale hydroelectric	0	0	1	1
MCHP	0	0	0	0
r-MCHP	0	1	0	1
Fuel cells	0	0	1	1
Heat recovery (i.e. MVHR)	10	5	14	29

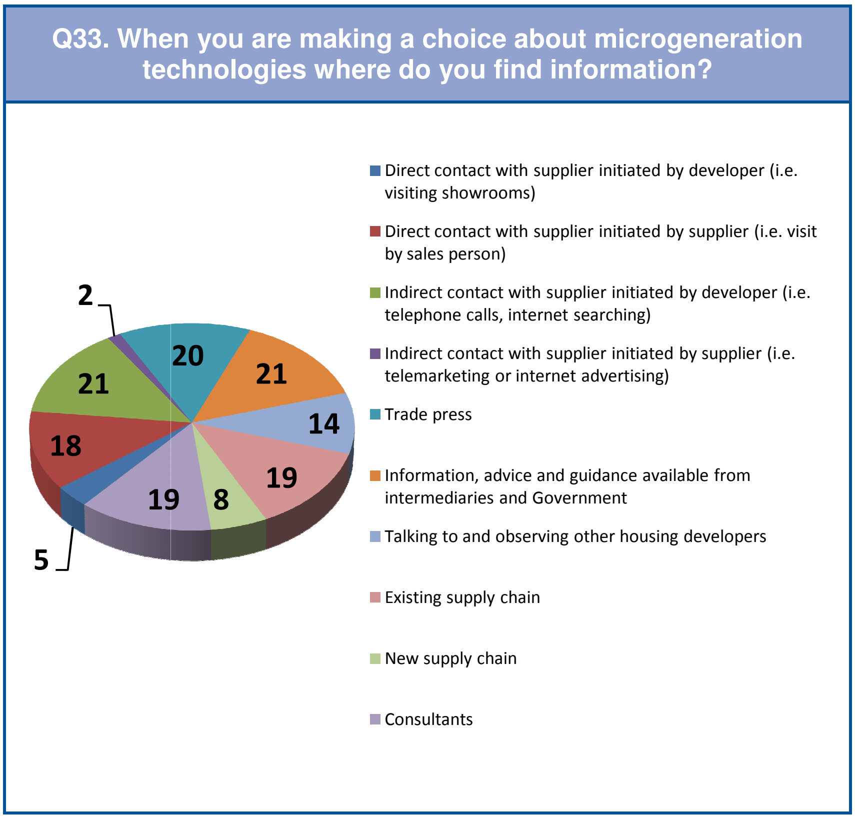
Q32. Which three technologies do you think are the MOST compatible with current building processes?



Question 33 When you are making a choice about LZC technologies where do you find information?

A range of different sources of information are used.

Source	Frequency
Direct contact with supplier initiated by house builder (i.e. visiting showrooms)	5
Direct contact with supplier initiated by supplier (i.e. visit by sales person)	18
Indirect contact with supplier initiated by house builder (i.e. telephone calls, internet searching)	21
Indirect contact with supplier initiated by supplier (i.e. telemarketing or internet advertising)	2
Trade press	20
Information, advice and guidance available from intermediaries and Government	21
Talking to and observing other house builders	14
Existing supply chain	19
New supply chain	8
Consultants	19



Question 34 On a scale of 1 to 5 please indicate how much you agree with the following statement. *"I find it easy to find robust, independent certification stating the performance of this technology."*

Certification is easier to find for solar based technologies.

Technology	1. Disagree	2. Somewhat disagree	3. Neither agree or disagree	4. Somewhat agree	5. Agree	Do not know
Biomass systems	17	10	7	9	3	10
Solar photovoltaic systems	11	5	7	16	13	4
Solar hot water systems	7	7	8	16	14	4
Wind power systems	12	6	13	6	4	15
Ground source heat pumps	9	14	8	10	5	10
Air source heat pumps	8	12	12	11	5	7
Absorption heat pumps	6	4	8	5	4	29
Small-scale hydroelectric	6	3	7	8	0	32
MCHP	10	3	8	6	5	23
r-MCHP	11	5	7	6	2	25
Fuel cells	6	4	8	5	1	32
Heat recovery (i.e. MVHR)	5	8	9	10	15	8

Question 35 On a scale of 1 to 5 please indicate how much you agree with the following statement. *"I am confident that if I installed this technology in a new home today it would perform as per the manufacturer's technical information*."

Confidence is higher in solar based technologies, MVHR, ASHP and GSHP. There is low confidence in wind power systems.

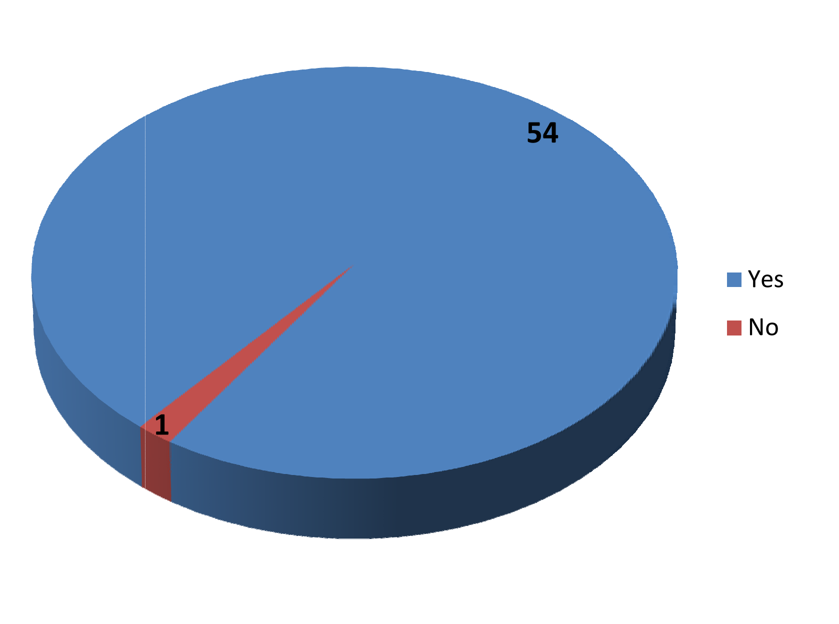
Technology	1. Disagree	2. Somewhat disagree	3. Neither agree or disagree	4. Somewhat agree	5. Agree	Do not know
Biomass systems	13	9	11	11	4	9
Solar photovoltaic systems	7	8	10	21	10	1
Solar hot water systems	6	7	11	20	12	1
Wind power systems	15	9	9	8	2	14
Ground source heat pumps	9	12	10	13	3	9
Air source heat pumps	8	10	14	14	3	8
Absorption heat pumps	5	6	9	7	2	27
Small-scale hydroelectric	4	4	9	6	2	31
MCHP	6	6	6	6	6	6
r-MCHP	8	5	8	7	3	26
Fuel cells	5	4	9	5	2	32
Heat recovery (i.e. MVHR)	4	9	15	15	8	6

Question 36 If you chose to install a low or zero carbon technology would you expect this technology to come with a manufacturer's warranty?

Almost all respondents expect a warranty.

If you chose to install a low or zero carbon technology would you expect this technology to come with a manufacturer's warranty?	Frequency
Yes	54
No	1

Q36. I would expect a manufacturer's warranty.



Question 37 How easy do you believe it would be to pilot each of the technologies below on a small scale in the company you work for?

The solar based technologies are identified as easy to pilot along with to a lesser extent air source heat pumps and heat recovery systems.

Technology	1. Difficult to pilot	2. Somewhat difficult to pilot	3. Neither easy or difficult	4. Somewhat easy to pilot	5. Easy to pilot	Do not know
Biomass systems	19	16	8	8	4	2
Solar photovoltaic systems	4	5	11	14	21	1
Solar hot water systems	3	7	6	16	24	1
Wind power systems	19	15	6	6	5	4
Ground source heat pumps	12	16	9	10	6	2
Air source heat pumps	7	7	11	17	12	2
Absorption heat pumps	6	3	12	8	3	24
Small-scale hydroelectric	19	8	5	3	2	19
MCHP	10	10	10	7	5	13
r-MCHP	13	10	8	4	4	17
Fuel cells	8	7	8	3	2	28
Heat recovery (i.e. MVHR)	5	4	14	13	16	4

Question 38 Please indicate how significant a role you expect each technology to play in the move towards zero carbon.

The solar based technologies are expected to play a significant role along with, to a lesser extent, air source heat pumps and heat recovery systems.

Technology	1. Significant	2. Fairly significant	3. Neither significant or not	4. Fairly insignificant	5. Insignificant	Do not know
Biomass systems	7	16	15	10	8	1
Solar photovoltaic systems	36	12	3	2	4	0
Solar hot water systems	32	18	1	3	3	0
Wind power systems	5	15	10	12	13	2
Ground source heat pumps	9	22	11	9	4	2
Air source heat pumps	11	25	11	4	4	2
Absorption heat pumps	4	10	8	3	3	29
Small-scale hydroelectric	2	9	4	6	14	22
MCHP	6	16	11	4	5	15
r-MCHP	5	19	6	6	5	16
Fuel cells	4	10	6	5	5	27
Heat recovery (i.e. MVHR)	21	20	5	4	5	2

Appendix B – Methodology for calculating 'positive percentage'

The innovation factors are expressed as a positive percentage in the technology profiles. This section sets out the methodology, and underpinning logic, to how this value is calculated.

It is important to note that Appendix A contains all of the responses received (even if the respondent did not complete the survey) and the technology profiles contain only the responses from respondents that completed the whole survey.

As we are considering factors that could influence the uptake of a technology it is appropriate to remove the 'Do not know' responses. The logic is that if someone does not know about a factor then it cannot influence their decision to use that technology or not. It is also convenient to compress the five point scale down to three points comprising positive, neutral and negative responses. Further, the middle, neutral responses are removed from the now three point scale. Again, the logic is that if someone indicates neutrally then this is not likely to inform their decision to use a technology or not. The metrics in the technology profiles is 'percentage positive response' which is the percentage after the 'Do not know' and 'neutral' responses have been removed.

Using MVHR as an example from Question 25:

Technology	Much easier	Slightly easier	Neither harder or easier	Slightly harder	Much harder	Do not know
Heat recovery (i.e. MVHR)	7	14	30	1	0	8

Compressing the scale down to three points gives us positive responses (21), neutral (30) and negative (1). The number of positive responses (21) far outnumbers the negative (1) but because of the number of neutral (30) the percentage calculated using the method above appears to be an underestimate.

Removing the neutral comments and the 'Do not knows' gives a new total of 22 and the following percentages. Positive (21/22)*100 = 95% and negative (1/22)*100 = 5%. It is this percentage which has been used in the technology profiles.

This value gives a more appropriate representation of those that have a positive response against those that have a negative opinion.

NHBC Foundation recent publications

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

Prospects for the UK house building industry

This report highlights that UK housing supply remains in deep crisis. It presents the results of a survey of senior house-building managers, social housing providers and industry experts to gather views on what is holding back housing supply. **NF 39** February 2012

The impact of occupant behaviour and use of controls on domestic energy use

Reducing the energy used for space heating, lighting and appliances is vital if the Government is to hit its carbon targets. This report reviews previous research and knowledge on how occupants use the controls in new housing and recommends that if energy efficiency is to be achieved that the attitudes and behaviour of occupants needs to be addressed. **NF 38** 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
- Energy-efficient fixed appliances and building control systems
- Recycled and secondary aggregate and cement replacement in residential construction
- Overheating in highly insulated homes

NHBC FOUNDATION

Housing research in partnership with BRE Trust

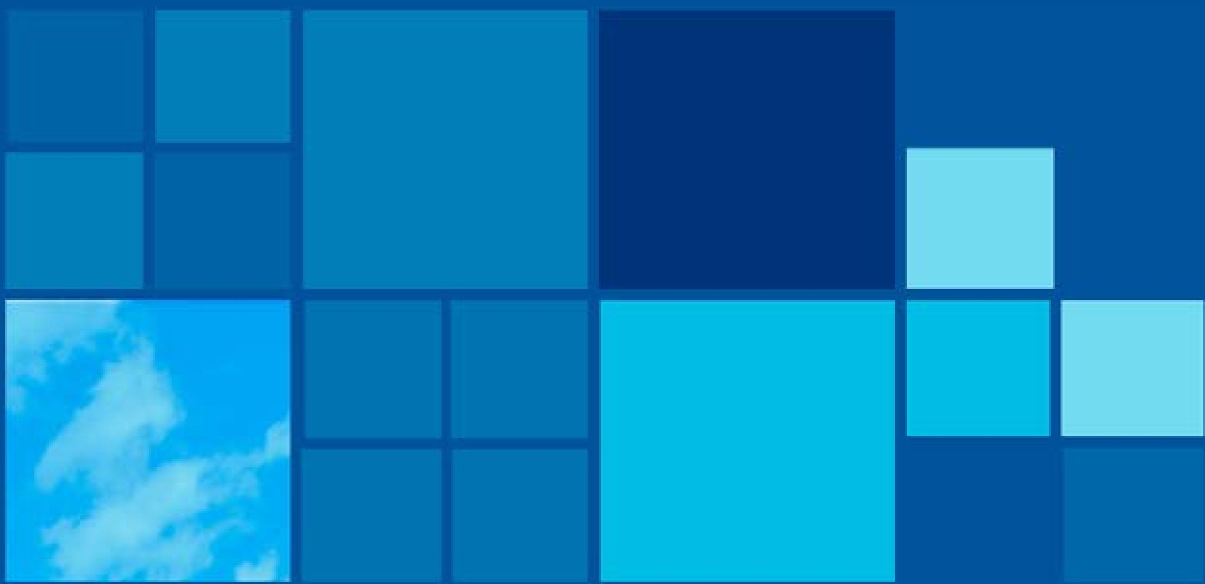
www.nhbcfoundation.org

Primary research

A survey of low and zero carbon technologies in new housing

This work has been conducted in partnership between the NHBC Foundation and the University of Reading. It examines which low and zero carbon technologies are being used by the house building sector in response to the challenge of producing low carbon homes.

Further it presents some finding on how occupants are using, adapting and benefitting, or not, from their low and zero carbon technologies.



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.

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