INVESTIGATING THE POTENTIAL FOR ACHIEVING LOW AND ZERO CARBON HOMES IN THE UK USING AN INTERACTIVE CODE FOR SUSTAINABLE HOMES BASED TOOLKIT

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ABSTRACT

This paper describes the development, application and analysis of an interactive user-friendly Code for Sustainable Homes based toolkit called Sustainability Appraisal Toolkit (SAT) commissioned by a leading UK social housing provider. The SAT software runs on MS Excel and is used to evaluate the technical and economical feasibility of achieving Code levels 4, 5 and 6 for a representative sample of new-build dwellings in the UK for different scales of development (single-home, 25-home and 250-home development). The research emphasises the importance of maximising energy efficiency improvements to the fabric and form of a dwelling, before adding optimum low/zero carbon systems (if required). The paper also concludes that a mix of energy technologies is required depending upon the site and scale of development, and the cost varies with scale to meet different levels of the Code.

INTRODUCTION

Scientific evidence shows that climate change is real and happening already, and that urgent action is needed now (IPCC, 2007). At the same time Kate Barker's (Barker, 2004) report into housing affordability has made it clear, that additional housing provision is required in the UK - if the houses needed are built, then by 2050 as much as one-third of the total housing stock is yet to be built. 27% of UK's CO_2 emissions arise from the energy used to heat, light and run our homes (Roaf et al., 2004). It is imperative that these homes are built in a way that minimises the use of energy and reduces their harmful CO_2 emissions. Houses also need to minimise other associated environmental impacts from water use, waste generation, and building materials. To account for this, in December 2006, the Communities and Local Governments launched a guidance called the Code for Sustainable Homes (the Code), which defines sustainability criteria for new houses.

Code for Sustainable Homes

The Code for Sustainable Homes (CSH) came into effect on 10 April 2007 and acts as the vehicle to facilitate the UK government's goal of ensuring that by 2016, every new house built in England is 'zero-carbon'. CSH serves as a guide to the direction of future Building Regulations (CLG, 2007b) and currently defines the national standard for sustainable design and construction of new homes. CSH took over form BRE's Ecohomes scheme (England only). The CSH defines six levels of sustainable development assigned through a detailed review at design and post-construction stages. At every level, it assigns mandatory performance criteria for energy and water consumption standards, three more categories have entry-level mandatory standards, and the remaining four are entirely flexible credits. Credits gained in each category are then multiplied with their environmental weighting factor to count as 'point scores' for each credit received. Each level is defined by the total number of 'points score' required to achieve that level. Table 1 shows how credits gained in each category compare against each other when multiplied with their environmental rating.

Table 1 Categories with environmental weighting

ISSUE CATEGORY	TOTAL CREDITS	WEIGHTING FACTOR	POINT SCORES
Energy	29	36.4%	1.26
Water	6	9%	1.5
Materials	24	7.2%	0.3
Surface water run-off	4	2.2%	0.55
Waste	7	6.4%	0.91
Pollution	4	2.8%	0.7
Health & well being	12	14%	1.17
Management	9	10%	1.11
Ecology	9	12%	1.33

As evident, energy and water have the highest point scores; hence, higher credits in these will amount to greater code 'point scores'

Since May 2008, all new homes require a mandatory assessment against the code, even if no specific Code level is targeted. However, compliance with higher code levels is mandatory to secure any government funding for housing projects. Mandatory code level 3 is required on all Housing Corporation and English Partnerships funded projects from 2008. Housing Corporation bids achieving a possible level 4 or above may score more favourably. Needless to say, CSH is an essential guidance, which directs the future of housing in the UK.

Within this context, the research objectives of this paper are to address the evaluation of new dwellings based on the criteria set out by the code. This paper describes the methodological approach for development of an interactive Sustainability Appraisal toolkit (SAT) which has then been used to assess the feasibility of achieving code levels 3, 4, 5 and 6 for three typical UK housing types, detached house ($104m^2$), mid-terrace ($79m^2$) and low rise purpose built flat ($61m^2$).

DEVELOPING THE SAT TOOLKIT

A sustainability appraisal toolkit (SAT) was developed as the first step towards assessing various scenarios of achieving different code levels. The architecture of the toolkit allows quick evaluations of designs and specifications to view their effect on achieving code credits. The toolkit comprises of the following elements:

I. SAT Credit Calculator
II. Water Calculator
III. Standard Assessment Procedure; SAP 2005 Worksheet, chosen according to the dwelling type
    a. SAP-Detached
    b. SAP-Mid-terrace
    c. SAP-Flats
    d. SAP-custom-built
IV. CSH-technical guidance document

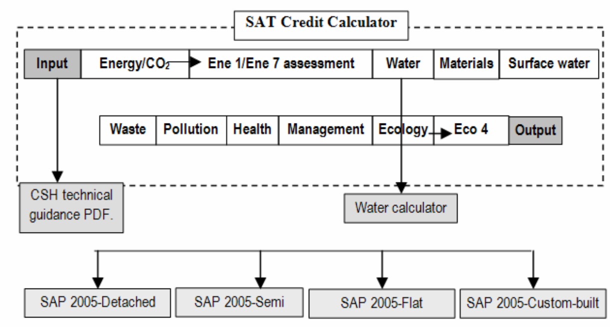

Figure 1 Architecture of the SAT toolkit

The '*SAT Credit Calculator*' is the main file, which is linked directly or indirectly to all other files in the SAT toolkit. The credit calculator has 13 sub-worksheets in all, one for each of the nine categories, a worksheet for calculating *Energy 1 & Energy 7 credits*, another worksheet to calculate *Ecology 4 credit*, an input file to select the type of house being evaluated and an output file which shows the results.

Code for Sustainable Homes - Sustainability Appraisal Tool

This toolkit is based on the technical guidance released in October 2007 and enables a pre-assessment of the probabale code level that can be achieved.

The tool is divided into 9 categories to achieve levels 1-6, with 6 being the highest level acievable.

There are three types of credits that are required -

Energy and water categories have mandatory credits required to meet each successive level (levels 1-6) of the code.

Waste, surface water run-off & materials have a mandatory entry level credit requirement (level 1) for any code level.

All other credits are tradable or flexible and add to the total credits for achieving a code level.

The code for sustainable homes should be evaluated separately for each 'dwelling type' in the development where the possible scoring for each dwelling may be different.

Name of the development	
Dwelling type (ID)	
Dwelling form	Detached
Dwelling description	

Overall points score and Code level achieved

Issue categories		Credits available	Weighting Factor	Probable No. of credits	% Score for Probable	Code level achieved
Mandatory Standards	Energy	29	0.364	14	17.5724	Level 3
	Water	6	0.09	3	4.5000	Levels 3&4
	Materials	24	0.072	10	3.0000	Mandatory level met
	Surface Water Run-off	4	0.025	3	1.8750	Mandatory level met
	Waste	7	0.064	3	2.7429	Mandatory level met
Tradable Credits	Pollution	4	0.025	3	1.8750	
	Health and well-being	12	0.14	7	8.1667	
	Management	9	0.10	8	8.8889	
	Ecology	9	0.12	8	10.6667	
				Total Points =	59.29	

Kg CO_2/m^2/year =	15.45
Tonnes CO_2/year =	1.22
Energy code level -	Level 3
Water code level -	Levels 3&4
Mandatory criteria -	Mandatory level met
% credit score level -	Level 3
Predicted overall code score:	**Level 3**

Code Levels	Total Points Required
Level 1	36
Level 2	48
Level 3	57
Level 4	68
Level 5	84
Level 6	90

Figure 2 Input & Output worksheet

The toolkit works on an individual house level. It allows the user to select the type of house being evaluated in *the input sheet* (*SAT credit calculator*) and then fill in the required data about building specifications in a corresponding *SAP worksheet.*

SAP is the UK government's adopted national methodology for calculating the energy performance and rating of dwellings and is used to show complaince with Part L of the building regulations (DEFRA, 2008). SAP simultaneously models a notional building of the same size, shape and use as the proposed building, but with 2002 Building Regulation energy performance values and assigns a Target Emission Rate (TER) to each dwelling. For compliance, the calculated annual carbon emissions from the proposed building, called the Dwelling CO_2 Emission Rate (DER) should be lesser than the TER.

The *SAP worksheets* are dynamically linked to the *Energy (ENE 1) and (ENE 7) Credit worksheet* for calculating the percentage improvement above TER *(ENE 1)* and the percentage reduction in carbon emissions achieved by use of low and zero carbon technologies *(ENE 7).* The results from these credits can then be input manually into the Energy worksheet.

The Water (WAT 1) credit requires extensive calculations to determine the amount of water consumption per person per day in the house being assessed. To aid with these calculations, a water calculator is dynamically linked to the SAP worksheets to pick up information such as the floor area and the number of occupants of the dwelling (Figure 3).

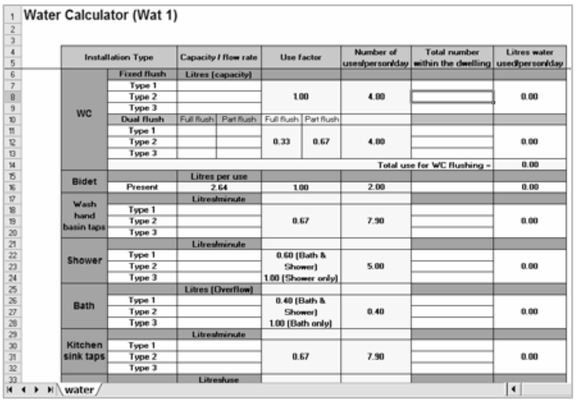

Figure 3 Water Calculator

Specific information about the number and type of water fixtures can be input into the calculator to estimate the water use per person in the house. The water calculator also allows the calculation of water saved by rain or grey water harvesting systems in the dwelling. Similarly, the results from other calculation sheets Ecology (*ECO 1)* and other CSH categories need to be completed. The result is displayed in the *output sheet* stating the Code level achieved for the overall dwelling. All results from the *SAT Credit Calculator and Water Calculator* worksheets were validated against the excel worksheets provided by the BRE for evaluation of CSH level ratings.

The toolkit is interactive and quickly responds to minor changes made in the *SAP worksheet* enabling designers to see the effect on achieving target code levels (Figure 4). The transparency of the toolkit also allows one to see absolute figures and compare one strategy against the other in terms of energy and carbon savings.

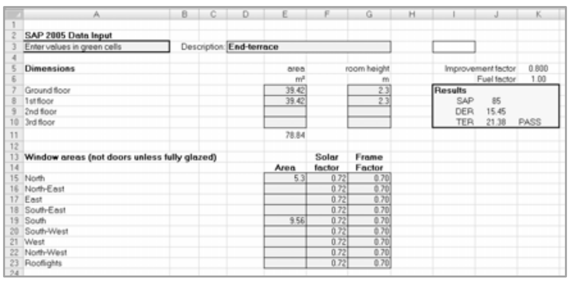

Figure 4 SAP Worksheet to analyse energy criteria

METHODOLOGY FOR APPRAISAL OPTIONS

The SAT toolkit was used to develop appraisal options for achieving levels 3, 4, 5 & 6 of the Code for Sustainable homes. Three typical house types in the UK were chosen as a representative sample for this study from the Standard Dwellings Configuration Report (BEPAC, 1990). The report provides a set of standard benchmark dwellings representing typical UK house types. The three chosen house-types were:

- Detached house (2 storeys) - 104m^2
- Mid-terrace house (2 storeys) - 79m^2
- Traditional low rise flat (up to 4 storeys)-61m^2

In addition, the SAT toolkit also allows the evaluation of any custom-built house requiring specific data to be input in the linked SAP files.

CSH defines nine categories for sustainability, but only energy and water categories have specific mandatory targets at each level and require calculations (Table 2). The rest of the seven categories, including mandatory and flexible credits, are 'checklist' credits. For the purpose of evaluating options for achieving different code levels, only the mandatory energy and water criteria (ENE 1 and WAT 1) have hence, been explored in detail in the project. The *ENE 1 Credit - Energy and CO_2 Emissions* is calculated based on the SAP worksheet and specifies percentage improvement in the Dwelling Emission Rate (DER) over the current building regulations part L, 2006 standards specified in SAP as Target Emission Rate (TER).

The *WAT 1 Credit - Internal potable water use* is calculated using the water calculator worksheet, and specifies the total estimated water use in litres per person per day. The following table specifies the mandatory design limits for both the criteria for different code levels.

Table 2 Design limits for energy and water

LEVELS	STANDARD (PERCENTAGE BETTER THAN PART L)	STANDARD (LITRES/PERSON/DAY)
Level 1	10%	120
Level 2	18%	120
Level 3	25%	105
Level 4	44%	105
Level 5*	100%	80
Level 6**	True zero carbon	80

*100% improvement implies zero emissions as per building regulations, i.e. emissions from heating, hot water and lighting.
**A true zero carbon home for level 6 also takes into account energy use for appliances and cooking.

Building fabric

CSH specifies a percentage reduction in carbon emissions over the notional baseline building regulations for energy use in new houses, and the levels are defined from 10% reduction to 100% reduction for a level 5 house that includes energy use for all space and water heating, and electricity for lighting (regulated energy use). For a level 6 house, electricity for cooking and appliances is also taken into account and this leads to a 150-170% improvement above baseline complaint house. CSH does not specify detailed design criteria or absolute design limits for meeting these demanding energy targets, as long as the dwelling is building regulations compliant and achieves the specified percentage improvement target for the code level.

This implies, that solutions can focus on only a low carbon approach which concentrate too much on low-carbon supplies (both renewables on-site and fuel supplies from outside). This seems to be a missed opportunity, especially because, new dwellings have the maximum potential of reducing energy use if built with a well-performing building fabric. This would also ensure a subsequent reduction in the associated carbon emissions. Moreover, an efficient building fabric is an approach, which is easily replicable across various house types and is not dependent on location related constraints such as availability of solar or wind potential or sufficient roof area etc. Hence, in this paper, to achieve technically and economically-feasible options, dwellings were modelled first, to maximise an energy-efficient fabric to reduce demand for energy, and then low and zero carbon technologies added to achieve percentage reduction of CO_2 emissions, for a respective code level. This is in line with our proposed 'low-energy first and then low-carbon' approach, in contrast with an approach which focuses on only 'low-carbon'.

Selected house types (detached house -104m^2, mid-terraced house-79m^2 and a low-rise flat-61m^2) are assumed to have typical specifications meeting the building regulations Part L 2006 criteria as their baseline performance standard for energy, also called the *base case* scenario. CSH does not specify detailed design criteria and hence, a number of available UK energy efficient standards were compared. The Passiv-haus target is the most commonly known European energy standard and defines a house which is built to a specification where it can heat or cool itself and hence 'Passive'. The design space-heating load is limited to around 15kWh/m^2/yr .

The UK Government's Energy Saving Trust (EST) defines three standards with design limits for a range of criteria as part of achieving the standard. Their *Good practice* target and the *Best practice* target relate to a 10% and 25% improvement respectively. The *Advanced practice* target defines absolute targets based on the Passiv-haus target, in addition to a percentage target (EST 2006). Due to their detailed specifications and reference to absolute targets, EST standards were found to be most appropriate for simulation purposes in this research.

The dwellings were therefore modelled in SAT to progressively stricter standards for fabric performance based on EST Best and Advanced practice standards to analyse their effect on space heating and other energy end-use demands relative to attaining the higher code levels. Further details used for modelling options from EST standards can be accessed from Appendix 1. Each dwelling type is assessed as an individual dwelling, as part of a 25-house development and as part of a 250-dwellings development. The different scales of development allow assessment of the feasibility of using community schemes to achieve different code levels.

In all, 24 options were evaluated across four levels of the code. Each option was first evaluated in the linked SAP worksheets specifying figures for fabric U-values, ventilation rates, air tightness, thermal bridging, space and water heating type with controls, and low and zero carbon (LZC) technologies. The results were then evaluated through the SAT credit calculator sheet to specify the level reached for energy.

Additional capital costs for energy and water

Costs are generally difficult to predict, especially costs for building fabric-related changes such as increased levels of insulation, double-glazing, etc as they are dependent on supplier chains, location aspects and development scales amongst other things. However to assess feasibility of different options in this study, it is important to relate to capital costs, as a key challenges in achieving higher code levels is the increase in capital costs (Cyrill Sweett, 2007). One of the more substantial costs for achieving higher code levels is that of the low and zero carbon technologies. Indicative costs for these systems have been provided (Table 3) to give an idea about additional costs that may be involved at each successive level of the code.

Table 3 Indicative capital costs used for Low & Zero Carbon technologies

TECHNOLOGIES	**COST**		
	LOW 250 HOUSES	**AVERAGE 25 HOUSES**	**HIGH SINGLE HOUSE**
Solar thermal 4m^2 flat plate	3200	3850	4500
PV 1kWp system	5000	6500	8000
Wind turbine per kW*	3500	5000	-
Biomass wood pellet boiler-20kW	5500	8750	12000

Note: All 'indicative' costs have been extracted from the Low Carbon Buildings Programme (/www.lowcarbonbuildings.org.uk/home).

*Costs for wind turbine have been derived from the British Wind Energy Association.

For achieving the water credits, additional costs over and above the standard specifications have been calculated. It is assumed, that the developer normally, would be bearing the cost of these standard fixtures. The costs beyond these specifications has hence, been shown as additional cost. A 5% discount has been taken into account for bulk purchase for 25 houses, and a 10% discount for 250 homes.

Table 4 Standard and additional water fixture specifications

STANDARD FIXTURES	ADDITIONAL SPECIFICATIONS AND COSTS
Non-controlled taps	Kitchen sink taps (3L /min) -£18/unit Hand Wash-basin taps (1.7L / min) - £18/unit
Single flush WC (6L)	WC dual flush (4L /2.5L) £53/unit
Standard bath (225L)	Small bath: (165L overflow) –£80/unit Small bath: (140L overflow)-£337/unit
Uncontrolled shower (flow rate of >15 L/ min)	Shower (6L /min) - £15/unit
Dishwasher (14L)	-
Washing machine (49 L)	Washing machine (45 L) - £36/unit
-	Rainwater harvesting system (individual) - £2520*
-	Rainwater/Grey water harvesting system (communal) - £680/unit*

Note: Water costs are derived (Environment Agency, 2007)
*Cost derived from (English Partnerships & Housing Corporation, 2007)

APPRAISAL OPTIONS

The SAT toolkit was used to develop 24 appraisal options for achieving levels 4, 5 and 6 of the Code for Sustainable homes. Detailed energy criteria were defined for three typical dwelling based on EST best and advanced practice standards (appendix 1). For all dwelling types, fabric performance relative to the EST's *advanced practice* has been taken as the base case to add low and zero carbon technologies for achieving requisite code levels 4, 5 and 6. Each dwelling type was assessed as an individual house, as a part of 25-house development and as a 250-house development. The water credits were calculated by specifying efficient fixtures and water re-use alternatives to minimise dependence on mains water. Table 6 provides the results as indicative strategies and costs for achieving code levels 4, 5 and 6.

Level 3

Level 3 of the CSH requires the Dwelling Emission Rate (DER) to achieve a 25% improvement over Target Emission Rate (TER), implying a 25% improvement over current building regulations. Level 3 is the mandatory requirement since 2008 for all English Partnerships and Housing Corporation funding streams and the energy criterion of 25% improvement is expected to be incorporated in the next building regulations update in 2010 (CLG, 2007a). As evident, it is the foremost level that the industry is trying to meet currently, especially large developers.

Table 5 shows the results for percentage improvement over TER achieved for different house types by applying the best practice and advanced practice standards. For both detached and mid-terrace house types, level 3 is achieved by the best practice standard. For a flat, however, the best practice target falls short of a 25% reduction. The results showed that in the absence of any absolute energy targets in CSH, smaller, more efficient dwellings such as flats are penalised and find it harder to achieve a similar percentage improvement over TER as larger, inefficient dwellings with a higher dwelling TER.

Table 5 Percentage improvement over TER

DWELLING TYPES	EST BEST PRACTICE (%)	EST ADVANCED PRACTICE (%)
Detached	29.40	42.85
Mid-terrace	27.76	36.38
Flat	22.75	30.73

Water design limit for level 3 and 4 is restricted to a maximum of 105L/person/day. Using water efficient fixtures it was possible to achieve this without the need for any water re-use scheme such as rain water harvesting or grey water recycling.

Level 4

Level 4 requires a 44% improvement over 2006 building regulations for the dwelling. Housing Corporation in the UK has already announced preference for schemes aiming to achieve a level 4 though it is not expected to be a requirement of mainstream funding till after 2010.Table 4 shows the strategies and indicative additional capital costs for achieving levels 4. The cost of a single detached and mid-terrace house including the additional cost for efficient water fixtures is around £4755 and £3630 respectively. The cost reduces for a 25-house development. For a flat the cost is even lower when shared with a group of 24 dwellings at about £2775. the costs can be expected to reduce further with community level strategies for 250 home development.

Level 5

Level 5 of the CSH, requires a 100% improvement over the 2006 building regulations. This means, that all energy accounted for in SAP, including, space and water heating and lighting must be either equal to zero or negative. Level 5 represents a big jump from level 4. The cost of achieving level 5 for a single detached and mid terrace house increases to about £29,000 and £23,000 respectively. Moreover, it was found, that while it was possible to achieve level 4 by savings through a communal gas fired CHP heating systems, a 100% reduction necessarily required a combination of more than one technology.

For achieving the water design limit of maximum of 80L/person/day, either grey water recycling or rainwater harvesting was required in addition to the use of extremely water efficient fixtures.

Level 6

Level 6 is the highest and the most difficult level to achieve for the industry, requiring not only very stringent standards for the building envelope, but accounting for all the energy the house uses, including the energy used for appliances. On an average, this represents a 150-170% improvement over the building regulations. This is mostly reflective of the electricity use for appliances being highly carbon intensive. As can be seen from table 6, the additional cost for a single detached house to achieve level 6 with the specific strategy proposed is estimated to be about £49,568 and around £41,643 for a mid-terrace. These are huge amounts and the industry needs to be prepared to deliver a very high quality of construction standards first to reduce energy use as much as possible within the house, and provide the remaining with LZC technologies. As with other code levels, reduction in costs can be expected for community level strategies.

Level 6 defines the 'Zero carbon house' that the government aims to achieve as the standard for all houses built from 2016 onwards. Currently, there is an ongoing debate about the definition of true zero carbon, as CSH only allows renewable energy to be counted towards reducing emissions for the house if it is directly connected by a private wire. This means, that all houses will need to establish their own private and direct connection to the energy source. Hence, any offsite renewables at present do not count towards carbon savings and cannot be used to achieve level 6. The policy is highly unlikely to be achievable for a large majority of the houses, especially those built in cities, where the provision of space and other natural sources such as the effectiveness of wind energy might be limited. A recently-published report by the UK Green Building Council (2008) points out that based on their study, around 10-80% of the new homes being built may not be able to meet the zero carbon targets as defined currently, and the government might need to reconsider the definition by allowing off-site renewables where on-site solutions are either very expensive or not possible (UKGBC, 2008).

CONCLUSIONS

Code for sustainable homes currently defines the national standard for sustainability of new homes and serves as a guide to the future building regulations. The construction industry is gearing itself to address the demands of achieving higher CSH levels. The Sustainability appraisal toolkit (SAT) was developed as an interactive tool to enable evaluation of design and construction specifications for achieving different target code levels.

The energy efficiency analysis to achieve a well-performing fabric shows that substantial savings in space heating energy and a greater percentage improvement over the baseline TER can be achieved if stringent standards are followed. In detached and mid-terrace houses, EST best practice standard is able to meet the criterion for Code level 3 energy requirements, while the advanced practice standard achieves about 40% improvement over the baseline TER. If strict, construction procedures and detailing are followed, these savings can be replicated across developments maximising carbon emission reductions. The analysis also shows that using the percentage improvement target from TER makes it easier for larger houses to achieve higher code level targets (104m^2 detached house), as compared to smaller efficient houses such as flats (61m^2) with a lower space heating demand.

Applying the SAT toolkit to achieve the required percentage reduction in energy, it was found that level 3 is achievable with a well-performing fabric, while level 4 requires some additional low and zero carbon technologies. The additional cost for a single detached house to achieve Code level 4 ranges from about £4755. The cost is reduced if the strategy is used at a community level for a 25-home development, with further reduction expected in a larger 250-house development.

Code levels 5 and 6 require a 100% improvement over building levels, with level 6 accounting for even appliance use. The additional capital cost for a single detached house to achieve level 5 is found to be around £29,168. For a level 6, it increases to around £49,568. This shows, how prohibitively expensive the higher code levels become due to additional LZC costs. It is hence, imperative to reduce energy use in the building as much as possible, before using LZC technologies for energy generation. Higher levels of savings can be expected from community level strategies.

It is concluded that a mix of energy technologies is required, especially to achieve higher code levels, depending on the site for different scales of development and the cost varies greatly in each scenario. It is hoped that these solution-based findings provide guidance to both public and private housing providers in achieving different levels of CSH in the coming years.

Table 6 Indicative strategies and costs for Low and zero carbon technologies

	Detached		Mid-terrace		Low rise flats	
	Key strategies	**Cost (£) /house**	**Key strategies**	**Cost(£) /house**	**Key strategies**	**Cost(£) /flat**
Level 4						
Single house	$4m^2$ flat plate solar thermal Efficient water fixtures	4500 255	$3m^2$ flat plate solar thermal Efficient water fixtures	3375 255	_	
	Total	**4755**	**Total**	**3630**		
25 houses *(24 flats)*	$75m^2$ flat plate solar thermal (3m2 each) Efficient water fixtures	2889 242	$75m^2$ flat plate solar thermal (3m2 each) Efficient water fixtures	2889 242	9.6kWp of PV panels shared (0.40kWp each) Efficient water fixtures	2600 175
	Total	**3131**	**Total**	**3131**	**Total**	**2775**
250 houses *(240 flats)*	Communal CHP with gas fired boilers Efficient water fixtures	Site specific 230	Communal CHP with gas fired boilers Efficient water fixtures	Site specific 230	Communal CHP with gas fired boilers Efficient water fixtures	Site specific 166
Level 5						
Single house	$4m^2$ flat plate solar thermal +2.7kWp of PV Efficient water fixtures + Rain water harvesting	26,100 3068	$3m^2$ flat plate solar thermal + 2.1kWp of PV Efficient water fixtures + Rain water harvesting	20,175 3068	_	
	Total	**29,168**	**Total**	**23,243**		
25 houses *(24 flats)*	Communal biomass boiler + 30kWp PV panels Efficient water fixtures + Communal Rain water harvesting	Site specific +7800 1200	Communal biomass boiler + 22.5kWp PV panels Efficient water fixtures + Communal Rain water harvesting	Site specific+ 5850 1200	Communal biomass boiler +24kWp PV panels Efficient water fixtures + Communal grey water harvesting	Site specific+ 6500 1133
250 houses *(240 flats)*	Communal biomass CHP + 140kWp PV panels Efficient water fixtures + Communal Rain water harvesting	Site specific+ 2800 1173	Communal biomass CHP 57kWp PV panels Efficient water fixtures + Communal Rain water harvesting	Site specific+ 1140 1173	Communal biomass CHP 84 kWp PV panels Efficient water fixtures + Communal Rain water harvesting	Site specific+ 1750 1109
Level 6						
Single house	$4m^2$ flat plate solar thermal + 5.25kWp PV Efficient water fixtures + Rain water harvesting	46,500 3068	$3m^2$ flat plate solar thermal + 4.4kWp of PV Efficient water fixtures + Rain water harvesting	38,575 3068	_	
	Total	**49,568**	**Total**	**41,643**		
25 houses *(24 flats)*	Communal biomass boiler + 37.5Kwp of PV + 2x15kw wind turbines Efficient water fixtures + Communal Rain water harvesting	Site specific+ 15,750 1200	Communal biomass boiler +30Kwp of PV + 2 x 15kw wind turbines Efficient water fixtures + Communal Rain water harvesting	Site specific+ 13,800 1200	Communal biomass boiler + 24kWp of PV + 2 x 15kw wind turbines Efficient water fixtures + Communal Rain water harvesting	Site specific+ 12,750 1122
250 houses *(240 flats)*	Communal biomass CHP + 750kWp of PV + 4x15kw wind turbine Efficient water fixtures + Communal Rain water harvesting	Site specific+ 15,840 1173	Communal biomass CHP + 625kWp of PV + 4x15kw wind turbine Efficient water fixtures + Communal Rain water harvesting	Site specific+ 13,340 1173	Communal biomass CHP + 483kWp of PV + 4x15kw wind turbine Efficient water fixtures + Communal Rain water harvesting	Site specific+ 10,938 1109

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Appendix 1 : Specifications of building regulations and EST standards

CRITERIA	**BUILDING REGULATIONS**	**BEST PRACTICE**	**ADVANCED PRACTICE (SIMILAR TO PASSIVHAUS)**
Target emission rate (TER)	DER<=TER	TER (best practice) = TER x 0.75	TER (advanced practice) = TER x 0.40
U-values	Roof: 0.25 W/m2K (0.20 W/m2K) Walls: 0.35 W/m2K (0.30 W/m2K) Exposed floors: 0.25 W/m2K (0.20W/m2K)	Roof: 0.13 W/m2K Walls: 0.25 W/m2K Exposed floors: 0.20W/m2K	Opaque <=0.15 W/m2K (Roof: Roof: 0.13 W/m2K)
Windows and doors	U-values <=2.2 W/m2K (Windows=1.9 W/m2K) (Solid doors=2.0 W/m2K)	Windows: BFRC rating band C or better (1.2 W/m2K) Doors: U-values <=1.0 W/m2K (solid)	Openings (glazing and frames) <=0.8 W/m2K
	Should conform to 'domestic Heating Compliance Guide'	Should conform to CHeSS HR6 or HC6 (2005)	Space heating <=15kWh/m2/yr Primary energy demand (all end uses) <=120kWh/m2/yr
Air permeability	Less than 10m3/m2hr at 50Pa (7m3/m2hr)	Less than 3m3/m2hr at 50Pa	Less than 1m3/m2hr at 50Pa
Limiting of Thermal bridging	Accredited construction details	Accredited construction details (<=0.04W/mK)	Practically eliminated, <=0.01W/mK
Ventilation	Purpose provided ventilation	MVHR 85% efficiency, 1W/(l.s) Specific fan power (SPF)	MVHR 85% efficiency, 1W/(l.s) Specific fan power (SPF)

Note: U-values mentioned are the limiting values for the standard. The value inside the parenthesis is the value used while modelling the baseline scenarios.

The advanced practice target has also been modelled with slightly higher air permeability (3m3/m2hr) and thermal bridging (0.03 W/mK) values to keep the target close to what is 'practically' achievable within the industry currently and not overestimate savings.

MVHR stands for Mechanical Ventilation with Heat Recovery