The Wates Conservation House at the Centre for Alternative Technology, and the Code for Sustainable Homes

Acknowledgements;

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Simon Tucker, Centre for Alternative Technology, October 2008

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1. Introduction

This report looks at aspects of the Code for Sustainable Homes based on a case study of the Wates House at the Centre for Alternative Technology (CAT). It does not attempt to describe the code in detail as this is already done in the code technical guide (DCLG (2007). There is a reasonable amount of published information on the code and references to a selection of these are given in the bibliography.

One aim is to provide an accessible introduction to the energy and renewable energy supply sections of the code. The energy and carbon emissions aspects are given the most weight in the code scoring system but are probably the most difficult parts of the code to understand.

A brief history of the house and its specifications is given in section 2 followed by an outline of the code in section 3. Section 4 looks in more detail at the energy and emissions aspects of code using the Wates house as a case study. This house although built over thirty years ago in 1975 addresses many of the energy aspects that the code is attempting to introduce to mainstream house building. Section 5 collates some existing information on renewable energy technologies in relation to housing, and section 6 gives the results of some brief modelling exercises that explore various renewable technology options. Finally in section 7 there is a discussion on selected aspects of the code and some conclusions.

2. The Wates House at CAT

2.1 History and specifications

A full account of the history, specifications and performance of the Wates house is given by Todd (*Energy and buildings at the Centre for Alternative Technology*, pp 6-13, undated) from which the information below is closely adapted. The booklet in now out of print but the information service at CAT retains at least one copy. All the information in the booklet concerning the Wates house has been included in this report.

Wates Built Homes were approached by CAT in 1975 to build a low energy house. For Wates, building the house would give them experience with the sorts of construction issues that result from super insulating otherwise conventional houses. CAT wanted also to explore and demonstrate how existing building and renewable energy technologies could contribute to a low energy house that could act as a prototype or model house. Wates Homes were keen on the idea, and an architectural practice (Peter Bond Associates) was given the job of designing the house.

The brief was as follows;

- The house was to be of fairly conventional appearance and size
- There was a budget of £20,000
- The main focus was to be on reducing energy demand rather than the supply. This was so that the house could potentially be built anywhere – not only where renewable energy was available. Therefore the house could be either connected to the mains or powered from autonomous sources.
- As a research project, it was concerned with the process of designing and building the house, and determining how heat losses could be minimised through use of thermal insulation, and how heat pumps could be used to help meet the reduced heat demands.

A further aim was to interest potential funding bodies in the possibilities of low energy housing.

The house has been modified several times over the 33 years since it was built and is currently used as offices on the upper floor and a demonstration house on the lower floor.

The heating and water systems have been changed over time but a basic description of the original house is as follows.

The house was the first house in the UK (and possibly in the world) to use ‘wrap-around’ insulation in that the same thickness of insulation (450mm) was installed all around the building, in the cavity walls, floor and roof. The house was designed to be of conventional appearance, and was laid out on two floors with a total floor area of 94 m^2. The majority of the glazing was to the south, with only small windows to the north and east elevations. There was just one door to the house which was accessed through a draft lobby.

Concrete block was used for the inner skin of the walls and provided significant thermal mass within the highly insulated envelope. Ventilation was mechanical with an air to air heat pump being used to heat the ventilation air. A water to water heat pump recovered heat from the waste water of the house. This energy was then used to heat the domestic hot water tank. A wind turbine provided power for lighting, and appliances such as the cooker were modified to use as little energy as possible.

Some problems were reported in the years after completion as follows;

- There was some condensation in the roof void due to lack of air circulation. The wrong material had been fitted under the eaves but apparently this was easily rectified (Todd, personal communication, 2008)
- Some spalling of the outer skin of brickwork occurred due either to, or to a combination of, the quality of bricks, the type of cement paint, but also perhaps the unusual temperature cycle of bricks which because of the super insulation could get very cold in the winter. There would also have been the possibility of condensate on inner surface of the outer bricks as the dew point occurred at the outer surface of insulation which might have frozen in very cold weather. However, drainage holes were provided in anticipation of this potential problem.
- The air – air heat pump fitted was unable to supply enough heat to the house in cold weather and was replaced.

Wates Built Homes used this house as a prototype building project. A small number were subsequently built in the South-East but with only 300mmm insulation (Paul Davies, Wates Living Spaces, personal communication, 2008).

The table below summarises the main features of the house as built. These are examined in more detail in section 4 alongside a description and discussion of corresponding aspects of the code.

Walls	Masonry cavity wall (U=0.075W/ m^2C) (ext-int) brick, 450mm 'dritherm' glass fibre insulation, thermalite block
Roof	450mm insulation, vapour barrier beneath insulation
Floor	Suspended timber over a concrete slab, 450mm insulation
Floor area	$94m^2$
Windows	Quadruple glazed windows
Space heating	Air-air heat pump with heat recovery from exhaust air
Water heating	Water to water heat pump recovering heat from waste grey water
Water supply (not drinking)	Rainwater collection from roof
Lighting	110V DC from wind turbine
Cooking	Insulated electric oven

Table 1.Features of the Wates House at CAT

2.2 Modifications to the house

The house has always been used as a demonstration building, but parts of it have provided at various times living accommodation for CAT volunteers, and office space for CAT. Various modifications have been made to support these different uses.

The plan of the house is rectangular with the long side facing south and brick services core offset from the centre of the plan resulting in a large space on the south orientation, a narrow circulation space the other side of the core (originally containing the staircase) and spaces at each end. It has proved adaptable – the internal partitions have been altered at various times and more recently the internal staircase removed and replaced with an external one at the North gable end. Currently the top floor is open plan office space and the ground floor a demonstration space. A sunspace / conservatory has recently been added to the south elevation.

The heating system has been changed several times. The air to air heat pump was replaced by a propane boiler supplying heat to two radiators, and currently the house is heated by a wood pellet boiler which is installed in a lean to garage/workshop structure added to the north elevation. Solar water panels now contribute to the water heating.

Overall, the house has proved to be adaptable and useful. Now, thirty years after the Wates house was built, the government and the housing industry is looking at how low energy homes (related specifically to carbon dioxide emissions) can be built as a matter of course by the mainstream construction industry. The Code for Sustainable Homes has been introduced as part of this activity.

3. The Code for Sustainable Homes

The Code for Sustainable Homes (referred to from this point as ‘the code’) is an assessment method which attempts to quantify the environmental impact of proposed housing developments. It was introduced in April 2007 for use by the private house building industry in England and initially was to be used on a voluntary basis. It replaced the previously used method of EcoHomes which is still used for refurbishment and for new housing in Scotland, Wales and Northern Ireland. Mandatory ratings for new house builds followed in May 2008 but at present an F rating is acceptable. However, from April 2008 all publicly funded housing was required to reach Level 3. By 2010 the requirement will probably be for Level 4 and by 2013, Level 6 (Cyril Sweett, 2007, p2).

There are also plans to improve the performance demanded by the Building Regulations. In order to achieve zero carbon homes by 2016 the following stages have been set out (NHER, 2008).

- Level 3 (25% improvement in energy and carbon emissions) by 2010
- Level 4 (44% improvement) by 2013
- Level 6 (zero carbon) by 2016

As an assessment method it defines energy and emissions standards in addition to standards for overall environmental performance. The areas addressed are shown in table 2 below.

Summary of Environmental impact categories and issues	
Categories	Issues
Energy and CO_2 emissions	Dwelling emission rate (M) Building fabric Internal lighting Drying space Energy labelled white goods External lighting Low or Zero Carbon (LZC) technologies Cycle storage Home office
Water	Internal water use (M) External water use
Materials	Environmental impact of materials (M) Responsible sourcing of materials – building elements Responsible sourcing of materials – finishing elements
Surface water run-off	Management of surface water run-off from developments (M) Flood risk
Waste	Storage of non-recyclable waste and recyclable household waste (M) Construction waste management (M) Composting
Pollution	Global Warming Potential (GWP) of insulants NO_x emissions
Health and wellbeing	Daylighting Sound insulation Private space Lifetime homes (M)
Management	Home user guide Considerate constructors scheme Construction site impacts Security
Ecology	Ecological value of site Ecological enhancement Protection of ecological features Change in ecological value of site Building footprint

Table 2. Code for Sustainable Homes impact categories and issues. Source: DCLG (2008)

Various points are available for these categories and issues, and in addition some minimum standards have been set for the first five categories as shown in table 3 below. The introduction of minimum standards in these categories means that these areas will always need to be addressed by house builders. Under the previous EcoHomes scheme trade offs between various categories could be made.

Code Level	Energy and Emissions	Water	Environmental impact of materials	Surface Water Run-off and management	Waste
	Reduction over 2006 Building Regulations (%)[1]	Maximum Potable Water Consumption (litres / person / day)		Peak run-off rates and annual volumes run-off	Site and household waste and monitoring
1	10	120	3 main elements[2] to be rated D or above as defined in 2007 The Green Guide	No greater than the previous conditions for the development site	Site management plan in place. Adequate space for waste storage in each dwelling
2	18	120			
3	25	105			
4	44	105			
5	100	80			
6	‘Zero Carbon’ Home	80			

Table 3. Minimum standards in the Code for Sustainable Homes. Source: DCLG (2008)

1. Technically defined as the Minimum Percentage reduction in Dwelling Emission Rate over Target Emission Rate (see appendix 1 for definitions)

2. The main elements of a house are considered to be the Roof, External Walls, Internal Walls (including separating walls), Upper and Ground Floors (including separating floors), and Windows

Total Credits available and Weighting Factors		
Categories of Environmental Impact	Total Credits in each Category	Weighting factor (% points contribution)
Category 1 – Energy and CO2 Emissions	29	36.4
Category 2 – Water	6	9.0
Category 3 – Materials	24	7.2
Category 4 – Surface Water Run-off	4	2.2
Category 5 – Waste	7	6.4
Category 6 – Pollution	4	2.8
Category 7 – Health and Wellbeing	12	14.0
Category 8 – Management	9	10.0
Category 9 – Ecology	9	12.0
Total	–	100.0

Table 4. Weighting of categories. Source: DCLG (2008)

A weighting and scoring system is used to arrive at a score for the housing development from which a code level is awarded, code level 1 being the entry level and at much the same level as BRE Ecohomes PASS level (DCLG, 2007, p18). Code level 6 is achieved by homes with ‘true’ zero carbon emissions (i.e. taking into account all energy use including that from cooking and appliances) and high environmental performance across all categories (ibid). Code level 5 is broadly equivalent to ‘Passivhaus’ standards in terms of dwelling emissions rate (AECB, 2007, p9), and code level 3 is similar to Ecohomes VERY GOOD.

From table 4 above it is clear that the single most important category is seen as Energy and CO2 Emissions. Over one third of all the available points are under this category which seems to be reasonable as reduction of emissions of greenhouse gases and mitigation of climate change are at present generally seen as the main priorities. The weighting of the individual categories is a topic for future discussion and debate.

There are criticisms that some of these minimum standards are not stringent enough, particularly in the materials category (see for example Wooley and Taylor, 2008). Other criticisms of details of the code are made in the building press and housing related websites and are summarised in section 7 below.

The house building industry is currently looking at how to meet various code levels with high profile demonstration projects at the BRE and elsewhere. The code seems to have been taken seriously by industry and it seems that it will gradually be improved and modified and integrated into Building Regulations in the future.

The following sections of this report look in some detail at selected aspects of the code. These aspects are chosen because they relate directly to the Wates House at CAT – to give a full examination and critique to every section and aspect of the code would require more space than is available here.

4 The Code and the Wates House

The Wates house was built over 30 years before the code was introduced and it is interesting to see how many of the concerns of the code were being addressed in this house at this time. Some issues were not specifically considered given the context of the site of the house at CAT and the different environmental priorities of the time. In this report the focus is mainly on the energy and emissions aspects of the house as these were the main reasons for building it, but low and zero carbon technologies were always part of the Wates project and these are discussed in this and following sections.

The energy and emissions category of the code has 36% of the total available credits assigned to it, reflecting its overall importance, and the Dwelling Emissions Rate (DER) accounts for over half of these within the overall category. Table 5 below shows how the Wates house would score in the energy and emissions category today.

Ene	Issues	maximum	obtained
1	Dwelling Emission Rate	15	12
2	Building fabric	2	2
3	Internal lighting	2	2
4	Drying space	1	1
5	Energy labelled white goods	2	2
6	External lighting	2	2
7	Low or Zero Carbon (LZC) technologies	2	1
8	Cycle storage	2	2
9	Home office	1	1
		29	25

Table 5. Energy and emissions category - scoring of the Wates house in its present form

We now look in more detail at the Dwelling Emission Rate, the Building Fabric, and Low or Zero Carbon Technologies.

4.1 Dwelling emissions rate (DER)

The Dwelling CO_2 Emission Rate is used to show compliance with building regulations in England and Wales (Northern Ireland from November 2006). It is equal to the annual CO_2 emissions per unit floor area for space heating, water heating, ventilation and *lighting, less the emissions saved by energy generation technologies, and is expressed in kg/m^2/year. (*EST, 2008a)

The DER is obtained by using the governments Standard Assessment Procedure (SAP) which is a simplified method of calculating energy use and CO2 emissions from housing. The emissions associated with appliances and cooking are not included under the current SAP but the calculation method is given in both SAP and the technical guide to the code and is expected to become part of SAP in the future (DCLG, 2007, p31). The calculation for cooking and appliances is done only when level 6 is being sought.

Criteria	
Percentage improvement of DER over TER	Mandatory levels
≥10	Level 1
≥14	
≥18	Level 2
≥22	
≥25	Level 3
≥31	
≥37	
≥44	Level 4
≥52	
≥60	
≥69	
≥79	
≥89	
≥100	Level 5
‘Zero Carbon Home’	Level 6

Table 6. Improvement required of carbon emissions and corresponding code levels

Table 6 shows the improvement required of the DER over the Target Emissions rate (TER) which is the emissions rate produced by an equivalent notional building performing to a standard as detailed in the 2005 building regulations *(*EST, 2008a). So a code level 3 house must perform 25% better than the notional example, and a code level 5 house must perform 100% better. The use of a notional equivalent to derive the TER has led to criticism, in that for example an air conditioned building will be compared with its equivalent (i.e. air conditioned) and a naturally ventilated building will be compared with its notional equivalent (a naturally ventilated building). The result is that it can be more difficult for energy efficient buildings (e.g. naturally ventilated) to reach the higher code levels as the improvement required is inherently more difficult due to the higher performance of its notional equivalent.

As stated above, the DER is the sum of emissions from space heating, water heating, ventilation and lighting less the emissions saved by energy generation technologies. These aspects will now be looked at individually.

4.1.1 Space heating

Todd reported the following of the Wates house;

- peak demand = 1.2 kW
- space heating requirement = 8kWh/day average in Dec and Jan
- space heating requirement = 950kWh over heating season (13,000 kWh for a typical house of same size at the time).

The space heating requirement is therefore equal to 10.1kwh/m^{2}yr. By comparison the Passivhaus standard requires a maximum space heating energy use of 15kwh/m^{2}yr (PHPP, 2007).

A dynamic thermal simulation program (IES, 2008) was used to investigate some variables of the house such as ventilation rate. The simulation results showed the space heating energy to be lower still, although the climate file available was for a nearby coastal location (Aberporth) where the temperatures may be slightly warmer than the overshaded quarry site at CAT. Table 7 below shows an almost negligible energy use when the combined ventilation and infiltration rates are 0.5 air changes per hour.

Air change rate (ventilation + infiltration) (air changes /hour)	Annual space heating energy	
	MWh	kwh/ m^2.a
0.5	0.106	1.1
0.75	0.529	5.6
1	1.154	12.3

Table 7. Thermal simulation results (space heating energy)

It was not possible in this study to tell exactly whether the initial monitoring was in error, or what aspects of the computer model fail to reproduce exactly the parameters of the building and climate. But clearly this is a very low energy building. When the air change rate in the computer model is set to 1 air change per hour, the annual energy use is still below Passivhaus standards.

As a final check on the model, space heating loads throughout the year were simulated (figure 1). The air change rate was set to 0.5 air changes per hour and the heating set point at 18C. The graph shows that the peak heating load in winter is 1.4 kW but is usually less than 1kW which agrees with the design calculations carried out in 1975.

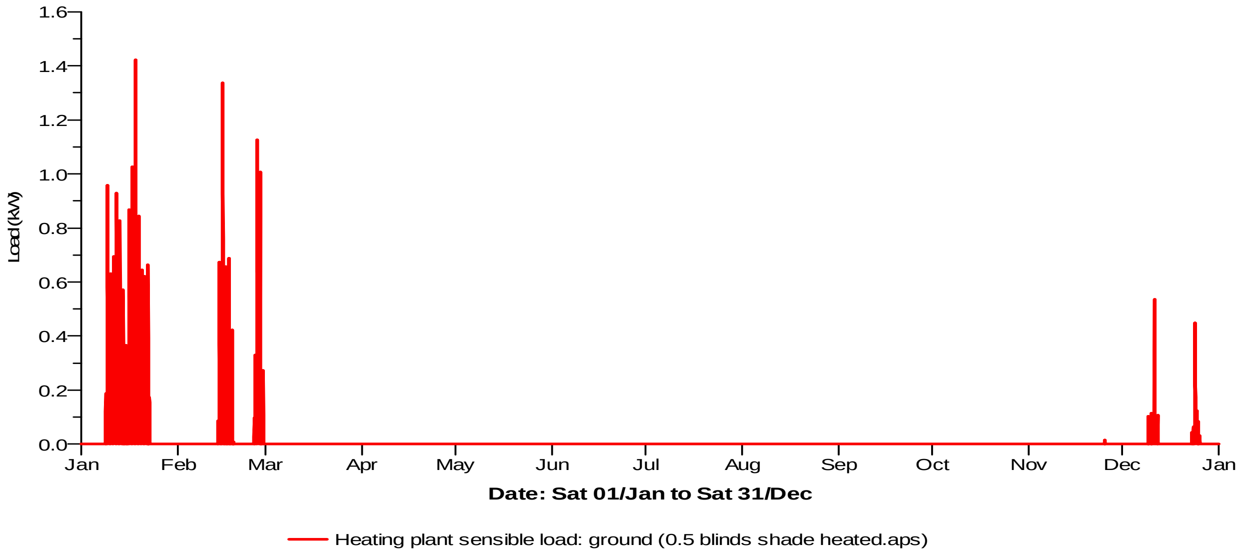


Figure 1.Wates House space heating loads at 0.5 air changes per hour

SAP calculates the space heating at of the house to be 47kwh/ m^2.yr (see appendix A). The monitored and the simulation results are far lower than this. It appears that SAP overestimates space heating energy use, although the set point temperature of 18C and the hours of operation in the actual house and in the thermal simulation model are lower than those assumed by SAP. However, it is quite possible that if code levels were determined using thermal simulation rather than SAP then the higher code levels may be easier to achieve with no increases in emissions. Further studies would be needed in order to determine whether SAP is being unduly pessimistic in its assumptions of how people use their homes. It is also possible of course that the inhabitants of the Wates house were particularly careful in their use of heating and therefore unrepresentative of the average inhabitant.

4.1.2 Hot water system

Waste water from the shower and sinks (no bath was fitted) drained to a 60 gallon waste water tank below the ground floor. The evaporator of the heat pump was immersed within this tank and the recovered heat used to heat a 40 gallon hot water tank to 50C. The system was monitored and the electricity to the heat pump was found to be approximately equal to the heat pumped into the house from the waste water
Total energy supplied was 4.5kwh/day or 1640kwh/yr. This was equivalent to17.44 kwh/m^2.year (all figures from Todd).

4.1.3 Ventilation

A 20W extract fan in kitchen drew air into house through creating a slight negative pressure within the house. A warm air heating system circulated fresh air at 0.25 ac/hr. Although no air leakage figures are available computer thermal simulation investigations compared with monitored energy figures suggest that the air change rate was probably higher than that intended. A pressure test would be useful although the house has been much modified since being built.

4.1.4 Lighting

A 110V DC supply from a wind turbine was used. The code allows for emissions savings from use of renewable sources to be accounted for.

4.15 Cooking

Energy requirements from cooking and appliances are only considered when code level 6 (true zero carbon) is being sought. To achieve this level requires a supply of renewable energy, as the emissions from fossil fuel derived energy (for cooking and appliance use) would immediately disqualify a building from ‘true zero carbon’ status.

Therefore, as is always the case with buildings, it is better to reduce the energy demand before providing a supply. In the Wates house a standard electrical oven surrounded by 150mm glassfibre reduced energy use by 50% (Todd). Electric saucepans were used instead of open rings as they were more efficient. Later an electric AGA was installed that could take intermittent power inputs of up to 8kW and could store sufficient heat to provide several days of cooking. This type of cooker is suitable for using off-peak and intermittent energy such as from wind turbines.

One can imagine future scenarios where night storage cookers become more common and which take advantage of a renewable energy generated at times of low demand. It could also be far cheaper to use domestic ovens as storage devices rather than develop large engineering projects such as pumped hydro schemes. In a well insulated house a storage cooker in a centrally positioned kitchen could provide the small amount of heat required to maintain comfortable temperatures in the house. The electric saucepans might not catch on though as at present a 5 litre pan can cost over £750!

Figure 2. An ‘Electra’ electric saucepan from circa 1920

In the future it may be the case that cooking and appliance energy will be taken into account in the calculation of code levels other than level 6 as it is possible that SAP will be updated in this respect.

4.16 Total energy use

The total primary energy use of the house is 106 kwh/m^2.yr (measured by SAP) and therefore meets Passive House standards for maximum total primary energy use of 120kwh/m^2.yr

SAP Rating	76
SAP Band	C
Environmental impact rating	95
Environmental impact band	A
Primary energy kWh/yr	9,966
Primary energy kWh/yr/m^2	106
Dwelling Carbon Emission Rate (DER) kgCO$_2$/m^2	5.33
Target Carbon Emission Rate (TER) kgCO$_2$/m^2	23.57

Table 8. SAP rating of the Wates House

4.2 Building fabric

4.2.1 Heat Loss Parameter

Credits are also awarded based on the Heat Loss Parameter (HLP) for each dwelling in accordance with the table below. The Heat Loss Parameter is defined as the total fabric and ventilation heat losses from the dwelling divided by the total floor area. This encourages a well insulated and airtight envelope.

Heat Loss Parameter (W/ m^2K)	Credits
<= 1.3	1
<= 1.1	2

Table 9. Heat loss parameter points

The inputs to SAP for the HLP requite U-values, ventilation and infiltration rates, and the level of thermal bridging. It is not known if the house has been pressure tested, and values of thermal bridging are also unknown. The Energy Savings Trust (GPG224) gives the following air permeability guidelines*:*

Ventilation system*	Maximum air permeability (m3/h/ m^2)	
	Good practice	Best practice
Dwellings with whole house mechanical ventilation (with or without heat recovery)	4	3
Dwellings with other systems	7	3

Table 10. Air permeability guidelines

HLP values derived from the SAP software for various values of thermal bridging and infiltration are shown in table 11 below. SAP inserts default figures where details are unknown by the assessor.

Calculation	Thermal	Infiltration	HLP

method	bridging		(W/ m^{2}K)
SAP	Unknown	Unknown	1.47
SAP	Accredited details	Unknown	1.3
SAP	Unknown	Good practice (4m3/hr.m^2)	1.15
SAP	Unknown	Best practice (3 m3/hr.m^2)	1.15
SAP	Accredited details	Good practice (4 m3/hr.m^2)	0.98
Original calculation	-	-	0.70

Table 11. Heat loss parameter values under various thermal bridging and infiltration scenarios

Todd calculated the specific heat loss rate at 66W/C. This is equivalent to a heat loss parameter of 0.702 W/m^{2}K and is far less than SAP calculates under any of the scenarios shown in table 11. The best HLP that SAP will give the Wates House is 0.98 W/m^{2}K, which is equivalent to a specific heat loss rate of 96W/C. However it is possible that thermal bridging was unaccounted for in the original calculations or that SAP is overly pessimistic in its modelling of the effects of bridging and air infiltration on heating energy use.

Todd's figure easily satisfies the requirement of a 'zero carbon home' to have an HLP of 0.8W/m^{2}K or less (DCLG, 2007, p31). But the SAP score is the one that is used in the code. As shown in section 4.1 above the actual space heating energy use is considerable less than SAP predicts it will be. All this throws further doubt on whether the SAP figures are good indicators of true emissions and in turn brings the validity of this part of the code into doubt. SAP is due to be updated in 2009, and therefore it remains to be seen whether the code level awarded for a development will accurately reflect the environmental impact of that development.

4.2.2 Guidelines on specifications

While the previous section is theoretical and focuses on SAP, to actually build a house involves specify building components and materials of a certain performance. Advice exists from the Energy Savings Trust as to what element performance should be specified to reach various code levels. Two examples related to the Wates house are;

Windows - the Wates House is fitted with Quadruple glazed windows with a U-value of approximately 1.54 W/ m^2C which is around the level 4 mark, although area weighted calculations can be applied here. Values of 0.8W/m^2C and 0.7W/m^2C are recommended for levels 5 and 6 respectively (EST, 2008).

Walls - the walls are constructed of:

brick – 450mm 'dritherm' glass fibre – thermalite block, *U=0.075W/m^2C*

This is far more insulation than generally required for levels 5 or 6. These levels require a U-value of around 0.14W/m^2k (about 240mm of EPS slab with a conductivity of 0.035W/mK (EST, 2008).If one takes the advice of the Energy Savings Trust then the Wates House is over insulated but then again windows with U-values of 0.7W/ m^2C were not available 30 years ago.

4.2.3 Insulation levels

Insulation levels were altered in the SAP software and the DER figures obtained for the Wates House. Because the SAP software used (Knauf, 2008) accepts U-values to 2 decimal points only, it was not possible to set exactly the correct thickness of insulation. The tale below shows the DER and Heat Loss Parameter (HLP) for various levels of insulation. The code level, credits awarded for DER, and credits awarded for HLP are shown also. The effective air change rate is set at 0.5 air changes per hour.

SAP U-value entered (W/ m^2K)	Equivalent insulation thickness in walls, floor, roof (mm)	SAP score	DER Kg Co2 /m^2.yr	HLP (W/m^2K)	CSH Level	DER credits	HLP credits
0.08	420	76	5.53	1.04	4	12	2
0.09	365	76	5.57	1.05	4	12	2
0.1	340	76	5.66	1.07	4	12	2
0.12	270	75	5.84	1.12	4	12	1
0.13	250	74	5.93	1.14	4	12	1
0.16	200	73	6.2	1.21	4	12	1
0.2	150	71	6.57	1.3	4	12	1
0.28	100	67	7.34	1.48	4	11	0

Table 12. Relation between code credits and insulation levels

The table shows that reducing the insulation thickness all around the building from 420mm to 340mm would not change the SAP score or the code credits awarded in the energy category (although this would change the actual energy use). The credits awarded for HLP would fall from 2 to 1 at about 300mm insulation but the HLP value depends also on ventilation and infiltration.

4.3 Low or Zero Carbon (LZC) Technologies

The Wates house at CAT has always had some form of renewable energy supply. Renewable energy is that which does not involve burning fossil fuels in its generation. This particular issue in the code is designed to encourage use of local energy generation from renewable sources. Electricity from the national grid bought under a ‘green tariff’ is not eligible for credits, but off site renewable energy supplied by an Energy Services Company (ESCo) or which is an ‘accredited external renewable’ is eligible (see DCLG, 2007, p59 for definition).

Assessment Criteria	
Credits are awarded based on the percentage reduction in total carbon emissions that result from using Zero or Low Carbon (LZC) Energy Technologies for each dwelling with credits awarded as detailed below:	
	Credits
Where energy is supplied from local renewable or low carbon energy sources funded under the Low Carbon Building Programme (or similar), or is designed and installed in a manner endorsed by a feasibility study prepared by an independent energy specialist	
AND There is a 10% reduction in carbon emissions as a result of this method of supply.	1
OR There is a 15% reduction in carbon emissions as a result of this method of supply.	2

Table 13. Credits available for use of Low or Zero Carbon (LZC) Technologies

The calculation method totals all carbon emissions generated by space heating, hot water, lighting fans and pumps, appliances and cooking, and then calculates CO2 reduction from use of LZC energy technologies. The following Zero and Low emission technologies may be considered;

Energy source	Technology	Emissions
Solar	Solar Hot Water	Zero
	Photovoltaics	Zero
Water	Small scale hydro power	Zero
Wind	Wind turbines	Zero
Other	Fuel cells using hydrogen generated from any of the above ‘renewable’ sources	Zero
Biomass	Biomass single room heaters/stoves Biomass boilers Biomass community heating schemes	Low
Combined Heat and Power (CHP)	CHP Biomass CHP	Low
Community heating including heating from waste		Low
Heat Pumps	Air source heat pumps (ASHP) Ground source heat pumps (GSHP) Water source heat pumps (WSHP)	Low

Table 14. Eligible Low and Zero Carbon (LZC) Technologies

In the Wates house the following technologies have been fitted at different times.

Solar Hot Water

Approximately 2m^2 of evacuated tubes have been fitted sometime in the last 10 years.

Wind

Originally a Dunlite 2kw wind turbine fed a 20kwh storage battery. This provided the power for a 110V DC lighting system. Todd reports that this system was adequate and reliable over a period of three years despite the wind turbine being less than ideally situated. DC systems are inherently more efficient than AC as there are no inverter losses. Some house designers are now leaving roof space for PV even if it is too expensive to fit at present. This seems sensible as future developments in PV technology might reasonably be expected to decrease prices and increase efficiencies.

Although the code provides credits for making use of renewable energy technologies as well as for improvements in the Dwelling Emission Rate, there are no credits for adding features to the building such that it may give rise to fewer emissions in the future. The only credits available for building flexibility are in category 7 (Health and well-being – lifetime homes). Perhaps credits should be available for ‘future proofing’ such as provision of roof space suitable for PV or for providing a degree of flexibility with regard to services such as ensuring they are easily accessible and therefore easy to modify.

Biomass

A pellet boiler has been installed recently in a lean-to built against the east side of the house. This provides heat for radiators and for hot water.

Air source heat pumps

An air to air heat pump was used for space heating. The maximum heating load of just over 1kw meant that a small pump could be used. Outside air was mixed with air from the kitchen extractor fan and fed to a heat exchanger in the roof space. The warm air produced was passed through the underfloor voids and into the rooms and stale room air was removed through ceiling vents.

Defrosting of the heat pump, and summer cooling to the house could be obtained by running the pump in reverse. Apparently the cooling was not required, but the heat pump itself was unable to provide heat on colder days due to icing. The icing reduced the COP from 2.5 to a point where heat could not be generated. Eventually a propane heater was installed outside the house which ran two radiators. The propane heater was later replaced with a pellet boiler.

Water source heat pumps

The water heating system was described in section 4.1.2. A heat pump immersed within the waste tank extracted heat until the waste water was at cold water feed temperature or less. Water was discharged from the bottom of the tank as further waste water was added. The heat gained was sufficient to heat a 40gallon hot water tank to 50C. This relatively low temperature ensured that the COP of the heat pump was maximized (it was measured at a value of 2).

The code uses SAP for hot water calculations. SAP has calculation options for;

- all water heated by heat pump,
- heat pump supplying 50% of the hot water with electric immersion supplying the other 50%
- immersion only

For heat pump only SAP requires multiplying the seasonal performance factor by a factor of 0.7 to account for the reduced efficiency of pump when heating the water to higher temperatures without the aid of an immersion heater. The water to water heat pump efficiency is given as 300% by SAP, so the adjusted efficiency would be 210%. SAP then requires a calculation for average efficiency for water heating – using the above figures this ends up as 135% or a COP of 1.35. The measured COP was 2 and the better actual performance is attributable in part to not heating the water to a higher temperature as SAP assumes.

A further influence on carbon emissions would be the source of electricity used for the heat pump and SAP will allow for this. Although there are many variables that can affect the system performance where heat pumps are used, the Wates house shows very well how thinking carefully about the systems of the house can result in savings.

It is possible that water to water heat pumps could be used today perhaps in prefabricated bathroom units where heat could be recovered from greywater. It would be interesting to look at the economics of providing larger hot water tanks such that the COP of heat pumps and possibly the efficiency of solar water systems could be increased. The situation is complicated though by water use in homes tending to be lowered due to the use of water saving devices and equipment, themselves encouraged through awarding of credits in the code. However, the water aspects of code are now coming under scrutiny and it is becoming clear that this area of the code will need further work. Some further comments on the code in this respect are given in section 7.

5. Potential of renewable energy technologies

5.1 Summary

To reach code level 6, all emissions that are accounted for under the SAP 2005 methodology (space heating, water heating and lighting) plus those due to cooking and appliances must be zero or negative. In order to cut CO_2 emissions to this degree, in addition to a very well insulated dwelling, it is necessary to include some form of micro-generation or other form of renewable energy. This section of the study carries out a brief evaluation of existing literature and information on the use of renewable technologies in some housing developments on the UK in order to widen the context from the Wates house to larger housing developments related to use of renewables.

Over the last year a number of British institutions have put together good information on the potential of the RE Technologies in the British context. The main drawback these documents have is that most of the numbers presented in them refer mainly to estimates, as there is still not that much information available on the performance of existing applications.

The Town and Country Planning Association produced a document (TCPA, 2006) from which it was possible to generate the two charts presented in Figures 2 and 3 below.

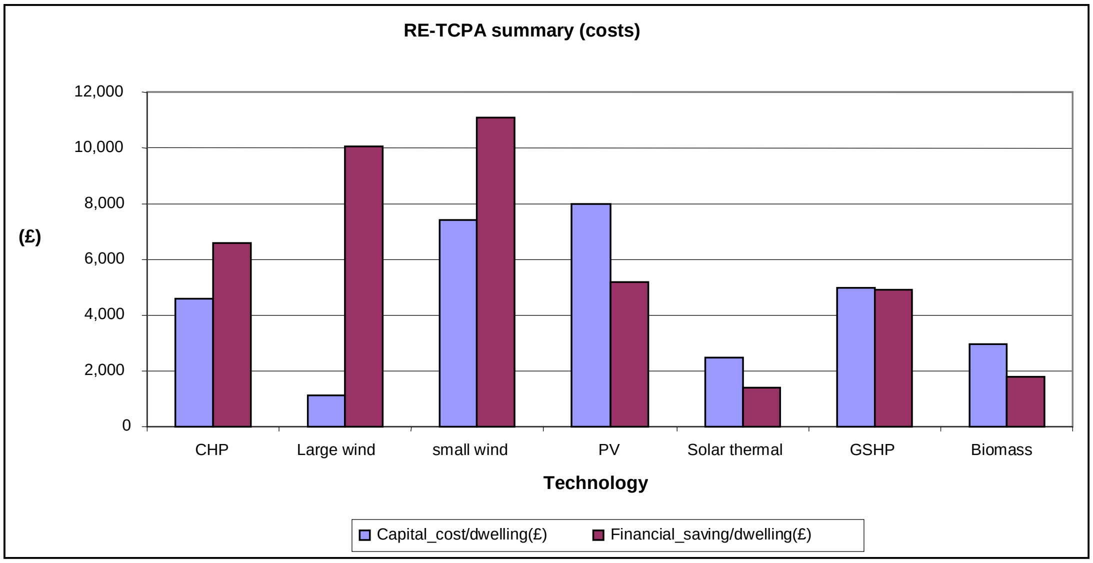


Figure 2. Costs/dwelling of deploying RE technologies

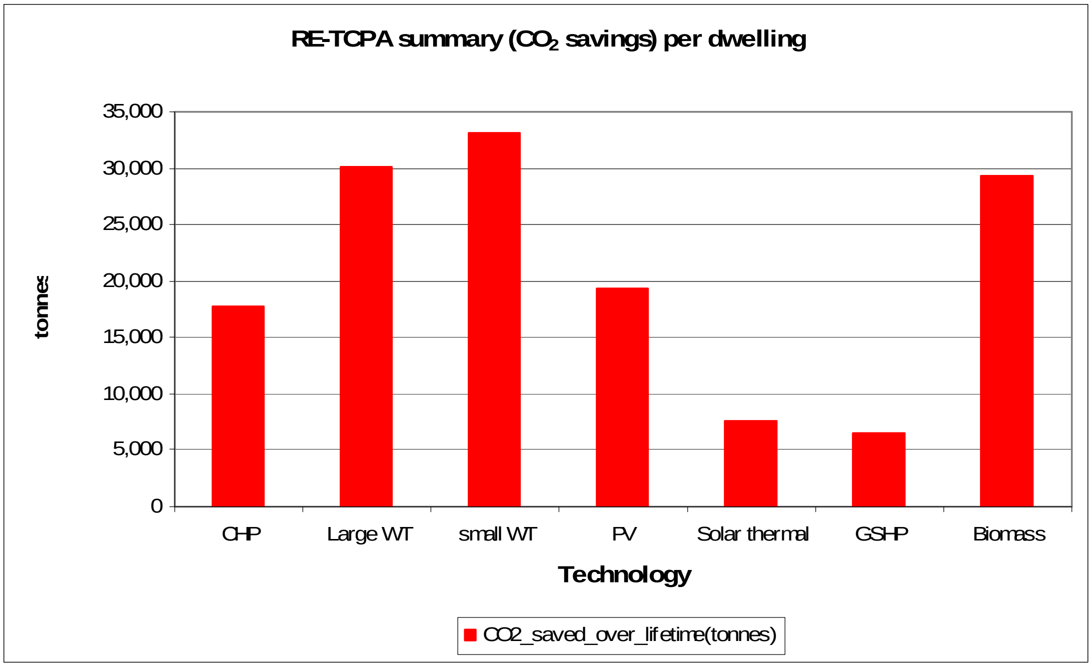


Figure 3. Potential savings of Carbon dioxide over lifetime

Figure includes the costs + savings that a typical dwelling incurs through the installation of a RE technology. These estimates indicate that the most effective technology is wind turbine as it provides the greatest savings over the lifetime of the technology, and also the least costs of installation. It is referring to a large system (at least 2.5 MW wind turbine) which will be shared amongst more than one household which will result (as the figure shows) in a cost reduction.

Figure shows the potential savings on CO2 emissions over the lifetime. The greatest savings are achieved with wind turbines. This is not surprising considering that the installations are supplying more than one dwelling and overall the system should provide a greater amount of CO2 reductions.

For communal heating and cooling networks to be viable in cost and efficiency terms, they need to supply dwellings which have been built to a minimum density of at least 30 dwellings or 100 people per hectare (TCPA, 2006).

It was also possible to produce similar charts from the data recorded in a document generated as a joint effort by the NHBC foundation and the BRE trust (NHBC & BRE, 2008).

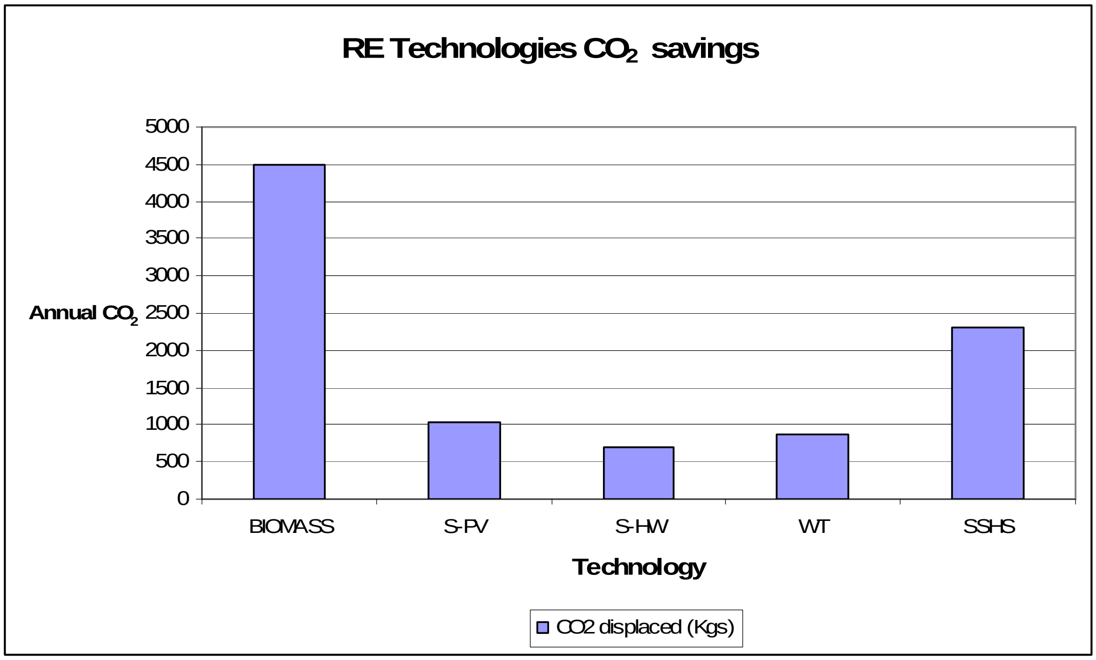
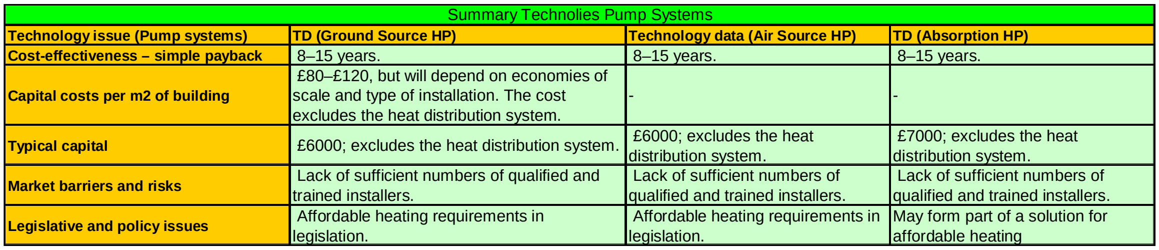


Figure 4 NHBC + BRE Trust Annual CO2 savings / Technology
(WT – wind turbine, SSHS - Small scale Hydro)

Figure shows the annual savings or CO2 displacements that can be achieved by installing the various RE systems. In each of these cases the savings shown are per installation, and the installation can be supplying more than one dwelling, although in all cases the estimates were generated for small systems.

The plot shows that the highest volume of CO2 savings is achieved through a biomass system. It is not top of the list as for the TCPA, nevertheless the results from both organizations are similar, but as the NHBC + BRE group did not include large wind turbine systems in their study, the conclusions reached regarding performance on CO2 savings will be different.

The ground source heat pump (GSHP) technology is not included in the plot because even though it was analysed by the organization, their main conclusion seem to indicate that it is not the best technology and therefore estimates were not included in the report. In addition to the GSHP, they looked at the air pump and the absorption systems and in all cases the final conclusion seems to be that there are better technologies available in the market. (see Table 1).



Summary Technolies Pump Systems			
Technology issue (Pump systems)	**TD (Ground Source HP)**	**Technology data (Air Source HP)**	**TD (Absorption HP)**
Cost-effectiveness – simple payback	8–15 years.	8–15 years.	8–15 years.
Capital costs per m2 of building	£80–£120, but will depend on economies of scale and type of installation. The cost excludes the heat distribution system.	-	-
Typical capital	£6000; excludes the heat distribution system.	£6000; excludes the heat distribution system.	£7000; excludes the heat distribution system.
Market barriers and risks	Lack of sufficient numbers of qualified and trained installers.	Lack of sufficient numbers of qualified and trained installers.	Lack of sufficient numbers of qualified and trained installers.
Legislative and policy issues	Affordable heating requirements in legislation.	Affordable heating requirements in legislation.	May form part of a solution for affordable heating

Table 14. Information on Pump Systems (source: NHBC + BRE Trust)

The information presented in Figure 5 also summarises the data found in the NHBC + BRE report. In this case it describes the typical capital costs for the technologies that were reviewed. The graph shows that the cheapest technology is Wind Turbine but it is necessary to take into consideration that the scenarios over which the estimates were generated are different in both cases. The Hydro system is not included in the plot because it is considerably more expensive (approx £165000).

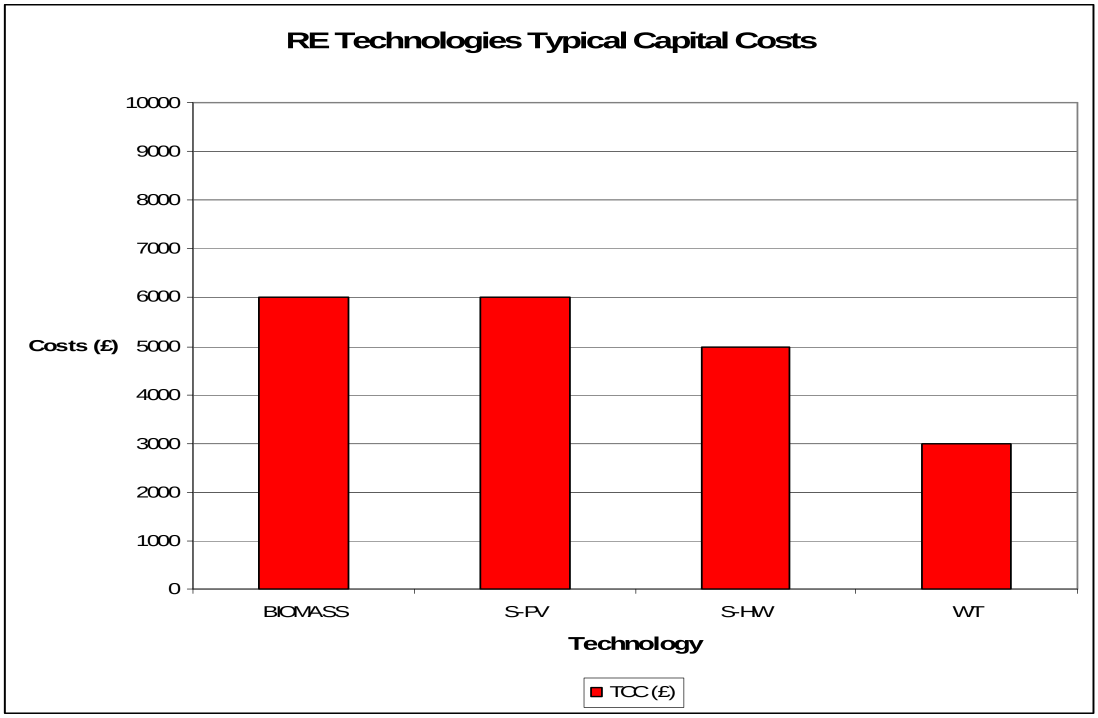


Figure 1 NHBC + BRE Trust data RE Technologies Capital Costs

The main conclusions that can be drawn from the material reviewed are as follows;

- The technologies that are more appealing correspond to PVs and wind turbines.

- The biomass system although it is an appealing solution with regards to the savings of CO_2 emissions, has the downside of not being the cheapest solution given that fuel needs to be continually purchased to keep it working, also the place in which it is installed, must provide reasonable storage space to keep the fuel. It is probably a cost effective option in a reasonable size development (> 1000 dwellings).
- The best available data on a biomass (CHP system) has been recorded through the BedZED project (Hodge and Haltrecht, 2008). The people involved have recorded a fair amount of data regarding their use of energy (both electricity + heat), and general performance given that their main interest is to become a zero carbon community. The aims were ambitious but there have been problems with the CHP system and more conventional energy sources have had to be used.
- The small scale hydro system is only a reasonable solution in very specific situations therefore not a good way to go in most cases.
- The pump systems are not really cost effective; their installation is fairly complicated (especially for refurbishments). Furthermore, their performance is not that good when considering the costs and electricity consumed to run the engine that pumps the heat.
- For large scale construction (1000+ homes) a wind turbine system is the most cost effective solution, but given its potential for not performing reliably 100% of the time, it should be combined with other technologies (e.g. PV, CHP) or connected to the grid.

5.2 Case Studies

This section summarises data from three case studies.

5.2.1 BedZED

[Information compiled from Hodge and Haltrecht (2008) and bioregional (2008)]

There are not that many examples in the UK of large developments (> 100 homes) which are supplied by RE technologies, have taken the trouble to record actual performance data, and are also prepared to release the information to the general public.

The BedZED development is the largest eco-village in the country. It consists of 100 homes that have been occupied since 2002.

Their energy demands are for electricity and heat (both space and water). These are met through the following technologies:

- Electricity and heat requirements at BedZED were to be satisfied by a wood-fired combined heat and power plant (CHP) using gasification.
- Additionally, each house at BedZED is fronted by a south-facing conservatory to maximise passive solar gain. Heat from the sun should make a substantial contribution towards heating BedZED houses to a comfortable temperature, thereby reducing the need for central heating.
- Photovoltaic solar panels were built into the roof fabric of the south-facing conservatories. The electricity generated from these panels was estimated to be sufficient to power 40 electric vehicles.
- Much of the water and energy savings at BedZED can be attributed to efficient appliances, so it is important that residents choose efficient replacements as appliances wear out.
- Electricity Consumption 2007. The average electricity consumption during 2007 was (Hodge and Haltrecht, 2008):
  - 3.4 kWh/ person/ day
  - 2579 kWh/ dwelling/ year
  - 34.4 kWh/ m2/ year
- CO_2 from electricity. Based on a conversion factor of 0.523 kg CO_2 per kWh electricity and assuming a 20% contribution
  - from the PV:
    - 1.4 kg CO_2/ person/ day
    - 1,079 kg CO_2/ dwelling/ year
    - 14.4 kg CO_2/ m2/ year

If the CHP had been working the results generated would have been those presented in Table . It is clear that a CHP system would result in great savings in CO2 emissions. In order to do this, it must be a workable system.

Energy	Units	BedZED-2007	BedZED-2007(if-CHP-in-operation)
Heating&hot_water	kWh/m²/yr	48	48
	CO2/m²/yr	9.3	1.2
Electrical_load	kWh/m²/yr	34.4	34.4
	CO2/m²/yr	10.6	-8.9
Total_Energy_use	kWh/m²/yr	82.4	82.4
	CO2/m²/yr	19.9	-7.7

Table 15. BedZED-2007, Total energy consumption and CO2 emissions per m^2 (residential)

Problems detected during their monitoring period in 2007 (Hodge and Haltrecht, 2008);

- Main technical problems with the CHP:
    - The design of new, untested equipment such as the automatic ash removal.
    - Reliability of some equipment that needed to operate continuously such as the wood chip grabber and slide valves.
    - Tar condensing from the wood gas.
- BP Solar's estimate suggests that the PV installation should account for 30% of the whole site consumption.
- Previous readings of the PV display use have been lower than this, and because the display board is no longer working, for the CO_2 calculations, a 20% contribution from PV was assumed.
- More monitoring is needed of the efficiency of solar power at BedZED.

The monitoring report for 2007 includes a detailed description of the complete BedZED experience during 2007, therefore it is worth reading as a good example of a real life example of a sustainable, zero carbon lifestyle.

5.2.2 Hockerton [Information compiled from HHP (2008)]

The Hockerton Housing Project (HHP) is the UK's first earth sheltered, self-sufficient, ecological housing development. HHP is located on the outskirts of Hockerton near Southwell, Nottinghamshire.

Their energy (electricity and heating) is supplied by a hybrid system, which supplies 5 dwellings. The contents in Table 17 include a profile of the energy use and occupancy of each house. The contents in Table 16 provide a list of the type of technologies used, the costs, and their capacity.

Renewable-System	Rating(kW)	Total-Installed-Cost(£)
Photovoltaic	7.6	40,650
Proven-wind-turbine	6	26,105
Iskra-wind-turbine	5	23,000

Table 16. Renewable systems at Hockerton

	Houses				
	1	**2**	**3**	**4**	**5**
Occupation profile					
Adults	2	2	1	2	1
Teens	0	0	1	2	0
Children	3	3	0	0	0
Key variability of facilities between homes					
TV[s]	0	1	1	2	0
Heat pump [water]	Yes	Yes	No	Yes	Yes
Home working	Yes	Yes	No	Yes	No

Table 17. Hockerton occupancy and appliances profile

It is not a big development but as they have a fair amount of performance data and how their requirements are satisfied by the renewable technologies deployed, it seemed appropriate to include them in this report.

Calculation average kWh produced/RE Technology			
	Apr (05-06)	May (06-07)	June (07-08)
PV	5539	6483	5211
Proven (WT)	4517	5264	3876
Iskra (WT)	4298	4647	5042
Total	14354	16394	14129

Table 18. Annual kWh of Energy supplied by the various RE Technologies over 3 years

The values in Table 18 correspond to the total kWh supplied to the Hockerton inhabitants by the hybrid system. The energy supplied is shared by the three systems, 2/3 is coming from wind turbines, and the rest from a PV solar system. The plot in Figure 5 shows how the energy requirements of the community and how it was satisfied by the hybrid system. It is clear that the system pretty well met their demand, although a small amount of the energy had to be supplied by an alternative source.

The picture over three years is fairly consistent, therefore it is possible to conclude that as far as small scale systems, a hybrid of PV and Wind Turbines is a good option.

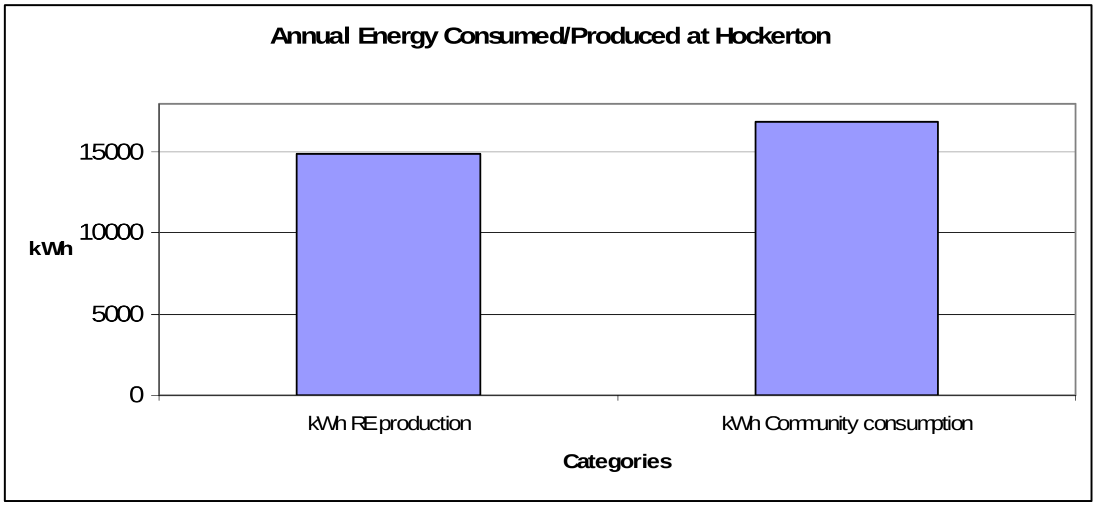


Figure 2 Hockerton kWh consumption vs kWh RE production

Case study 3: Beaufort Court (information compiled from BC (2008))

Another small development, in this case it is a non-domestic one, but as with he Hockerton case, it is a good example of the potential there is in a hybrid system and a fair amount of performance data is available from a reasonable period of time.

In this case their energy is supplied in the following way:

- Electrical energy is generated both by the wind turbine and by the photovoltaic (PV) modules within the solar panel array. This electricity can be used either within the buildings, or can be sold to the national grid for use by others when there is an excess.
- Heat energy is generated from the solar panels and the biomass boiler. The generation of solar heat is dictated by the weather. When solar heat is available and there is a heating demand, the energy is used directly to heat the incoming air into the buildings. In the summer, the excess heat produced is stored in the underground Heat Store for future use.

- The generation of heat from biomass is dictated by demand from the building, with the biomass boiler firing as required. The conventional natural gas boilers are used only when the demand for heat is greater than can be met by the solar and biomass sources.
- Cooling energy is provided by using water at around 12C pumped up from the 75m deep borehole. This is demand driven, with the borehole pump operation being controlled by the level of cooling needed in the buildings.

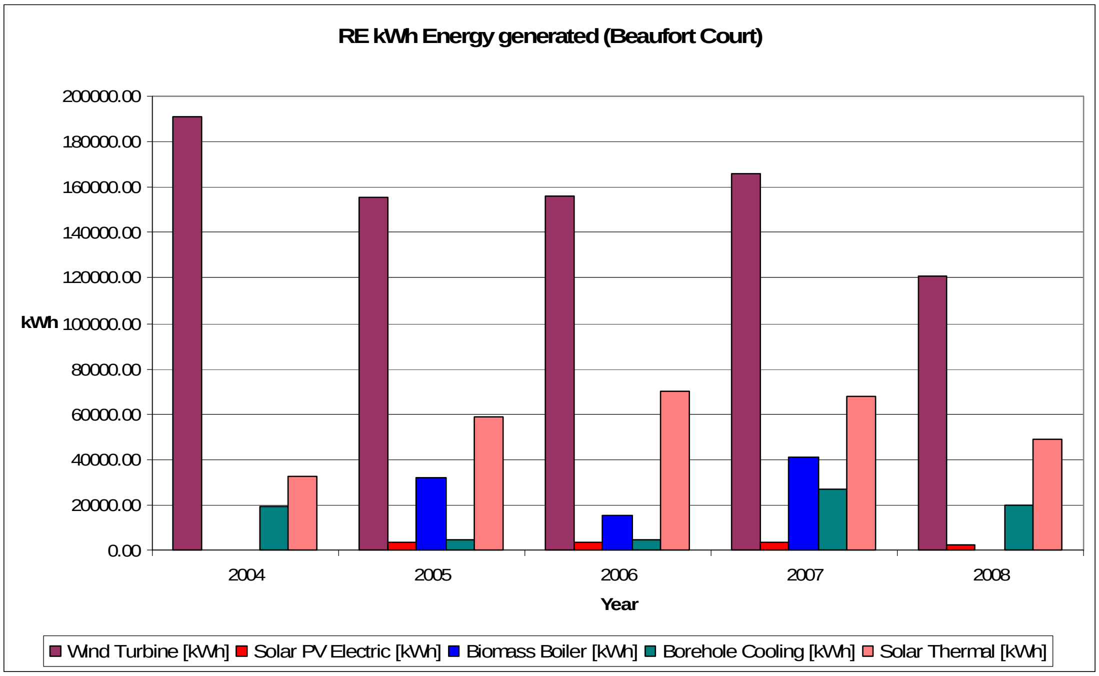


Figure 3 Beaufort Court kWh generated by hybrid system (2004-2008)

The plot in Figure 6 shows the amount of energy supplied by each of the RE technologies between the period 2004-2008. The largest amount of energy is supplied by the wind turbines. The solar thermal system also generates a significant quantity of energy. The biomass system and the PV Electric provide a small fraction of the total energy generated.

The wind turbine provides the highest amount of energy probably because it is the biggest system, but also because it has been in more continuous use than the biomass boiler which can produce similar amounts of energy when in operation (9).

Conclusions

Having looked both at the estimates and the actual data from the various organizations involved in the study and deployment of RE Technologies, it is clear that there has been considerable progress in the last decade, not only in improving existing technologies, but also in the development of new types, e.g. fuel cells.

So much variety makes life difficult for the potential customer; nevertheless there are a number of very good studies (TCPA, 2006), (NHBC & BRE, 2008) that give good information on the most effective technology for the most common scenarios.

In the UK, given its climate, it is not possible to rely in just one solution, the data from successful deployments all involved hybrid systems.

From the perspective of attempting to design a development that will be zero carbon and fully comply with the requirements of the code, it is clear that no matter how good the design is, its expected performance will only be as good as the behaviour of its occupants.

There has been quite a lot of publicity on the benefits of using biomass systems in an attempt to become zero carbon. It is also true these systems provide the highest savings in CO2 emissions when compared to other systems, nevertheless care must be taken when attempting this option given the problems encountered by users of existing applications.

6. Carbon scenarios

This section gives some examples of how renewable energy technologies, applied to housing developments might relate to the code. Some existing information has been summarized in section 5 of this report, but here the results of modeling are shown. This type of modeling could inform design decisions when housing developments under the code are being planned.

Financial costs are not considered here as they are beyond the scope of this report, but clearly these are a major variable and need to be included in any project study. Other main variables are;

1. The code level required
2. The size and type of the development
3. The renewable technologies to be used

It is relatively easy in theory to alter and experiment with these three variables to suit any particular site, and the comprehensiveness and usefulness of the modeling depends on the availability of data for the modeling and the time and resources available.

For mixed use developments it may be easier to achieve high code levels *and* good environmental performance, as due to the mix of building types there are greater possibilities for using CHP heat when otherwise it might be wasted (for example where it is used to generate cooling for offices in tri-generation systems).

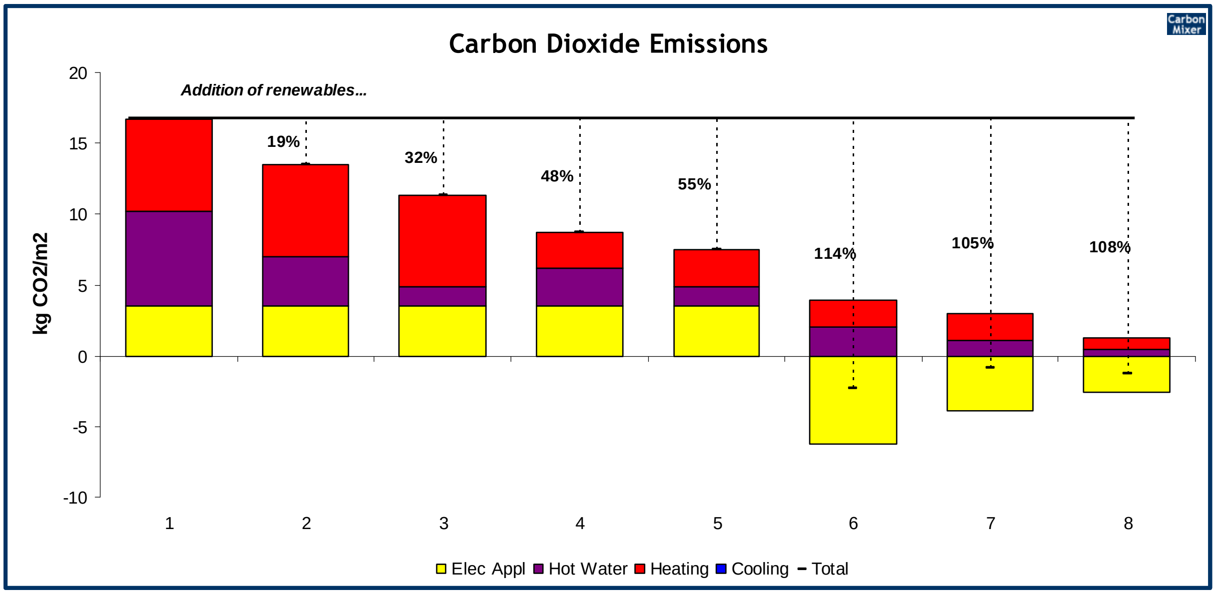
Other possibilities exist such as using excess CHP heat to heat nearby existing houses which may have poor thermal performance, or swimming pools etc. In this case the heat supplied would displace proportionally greater emissions per m2 and modeling would need to be done on a case by case basis, taking into account the operation and sizing and potential efficiencies of the CHP as well as the CO2 saved by replacing conventional energy use in the existing housing.

The efficiency of cogeneration plants (CHP) and/or community heating schemes depend on many variables such as size and efficiency of plant and heat/power loads, fuel type, and whether other energy sources are available. Because of the many variables and the calculations required to determine efficiencies of any particular mix of energy sources intended to provide for buildings, each development has to be treated individually.

Three examples follow that illustrate the type of studies that can be done. The software ‘Carbon-Mixer’ (ref) is used to obtain emissions results that can then be related to code levels. This software uses SAP figures for energy demands and, simplified data for the energy supplied through various renewable and non-renewable energy sources.

Addition of renewable technologies to a housing development

Thie first example shows non-renewable energy use and Carbon Dioxide emissions per unit floor area for a development of 350 homes (floor area 100m2 each). The homes are detached ‘Wates homes’ with equivalent thermal performance to the example at CAT. Case 1 (see figures x, x and table x below) is fitted with a 90% efficient gas boiler. Taking this as a base case a range of renewable technologies are added which result in changes in the DER and hence the resulting code Level. Some of the scenarios indicate that only a certain percentage of the heat demand is supplied by for example a wood chip boiler (e.g. sized for base load in a communal scheme). Here the remainder of the heat is supplied by the gas boiler. None of these scenarios consider cooking and appliance loads and hence are not eligible for Level 6, but this situation could easily be modeled.



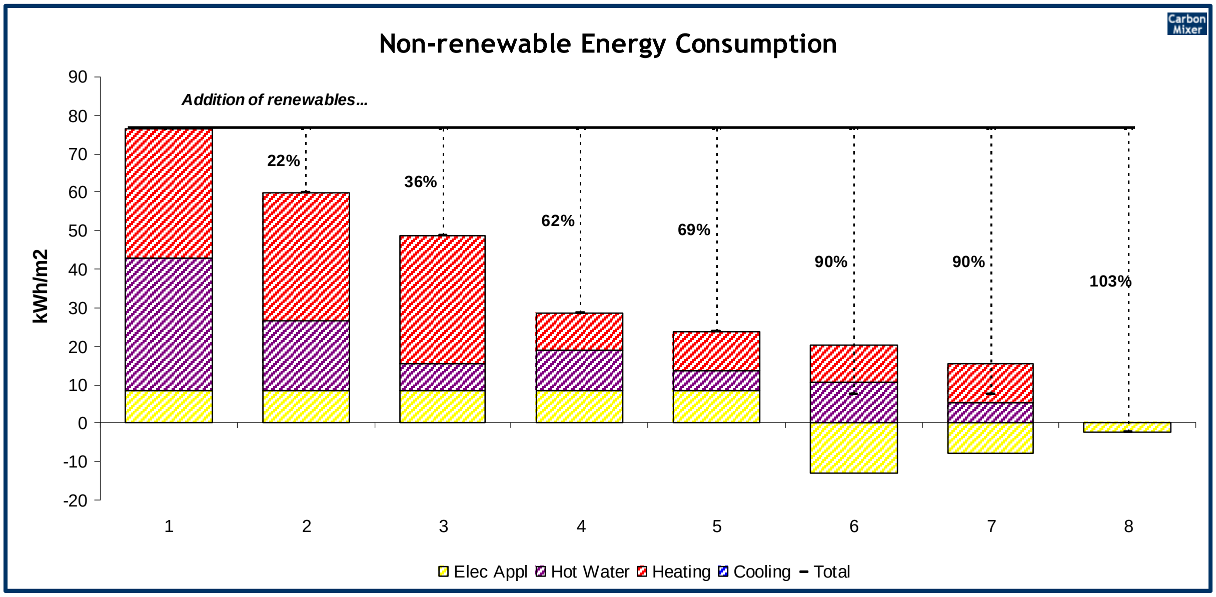


Figure x. CO2 emissions due to electrical appliances, hot water and heating (per square meter floor area)

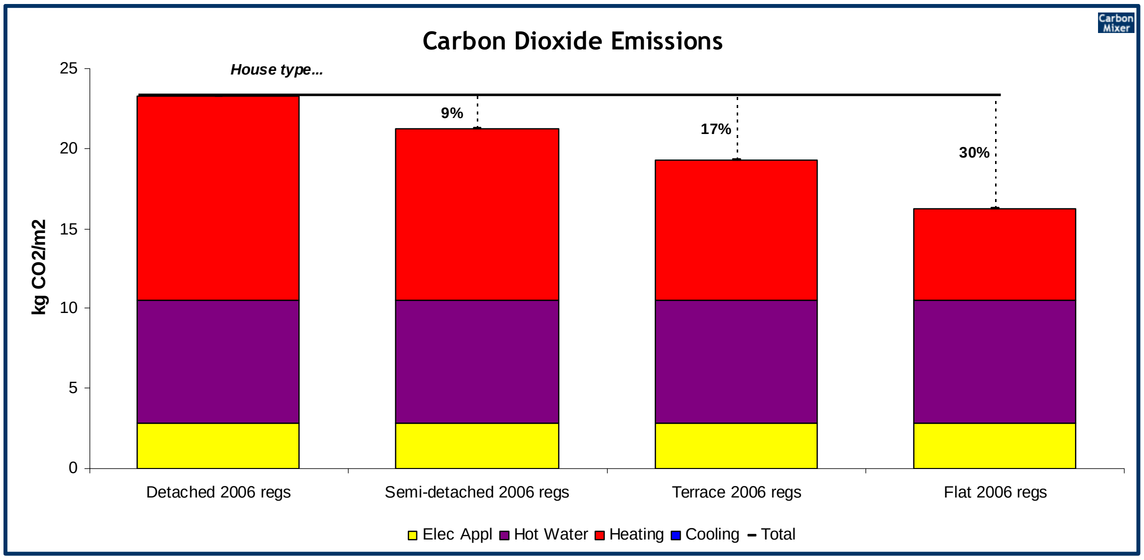
1. Base case. Domestic gas boiler (90% efficient) + grid electricity for lighting
2. Base case + 3m^2 Solar Hot Water per house
3. Base case + 5m^2 Solar Hot Water per house
4. Wood chip boiler (85% efficient) supplying 70% of heat demand
5. Wood chip boiler (85% efficient) supplying 70% of heat demand + 3m^2 SHW per house
6. Woodchip CHP supplying 70% of heat demand
7. Woodchip CHP supplying 70% of heat demand + 3m^2 SHW
8. Pellet boiler (90% efficient) + 3m^2 SHW + 10m^2 PV

	Energy source	DER (kgCO2/m2.year)	% reduction of DER from TER	code level
1	Gas boiler (base case)	16.71	29.10	3
2	Base case + 3m2 SHW per house	13.49	42.77	3
3	Base case + 5m2 SHW per house	11.34	51.89	4
4	Wood chip boiler (85% efficient) supplying 70% of heat demand	8.73	62.96	4
5	Wood chip boiler (85% efficient) supplying 70% of heat demand + 3m2 SHW	7.45	68.39	4
6	Woodchip CHP supplying 70% heat demand	-2.27	109.63	5
7	CHP woodchip supplying 70% heat demand + 3m2 SHW	-0.863	103.66	5
8	10m2 PV + 3m2 SHW + wood pellet boiler (90% efficient) supplying 100% demand	-1.298	105.51	5

The base case achieves code level 3 and adding 5m^2 of SHW brings it up to level 4 (although in this case 3.5 m^2 would be enough for level 4). Level 5 is reached when a mix of technologies is applied. The example here uses biomass CHP or a mix of PV, SHW and a wood pellet boiler. Note the reduction in improvement of DER over TER between cases 6 and 7. When SHW is added in case 7 the CHP needs to supply less heat for hot water and so produces less electricity. As the CHP is assumed to provide only 70% of heat, more gas is used in the backup boiler in case 6.

Effect on energy use and emissions of house type

It is also interesting to see how house type can influence emissions. Figures x and 3 below give an indication of the different loads in different house types built to 2006 building regulations (all using gas boiler only, with identical construction and floor area).The differences in the emissions figure are due to the variation in area of external envelope exposed to the outside air.



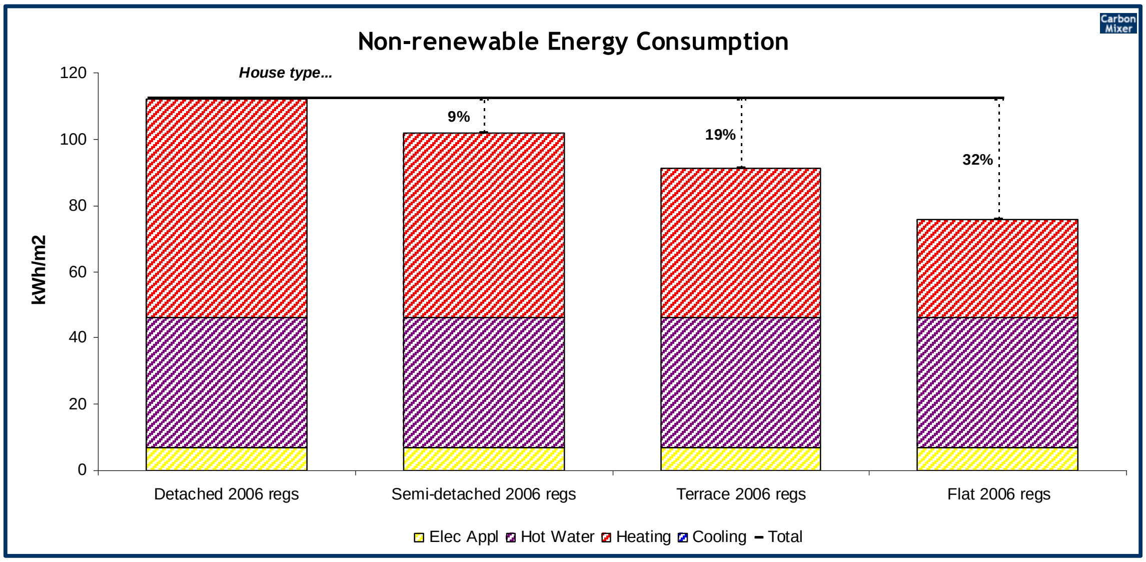
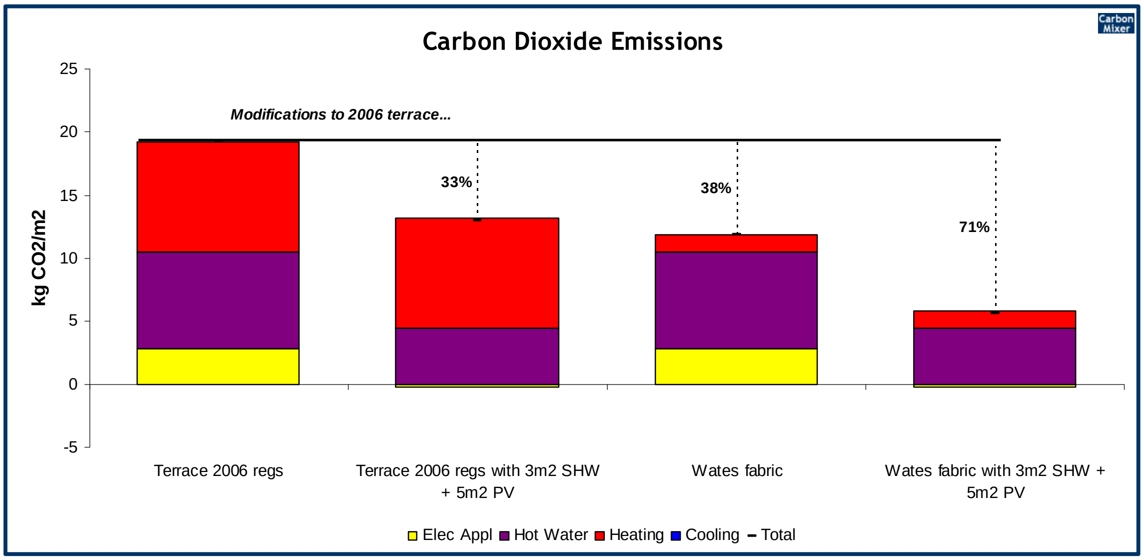


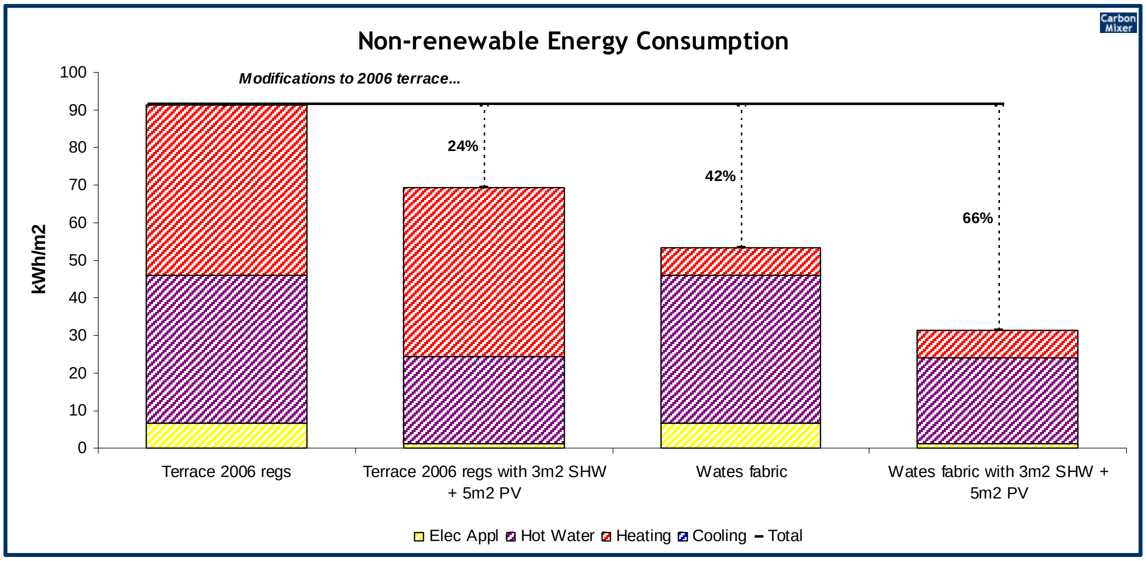
Figure x. Carbon emissions for various 100m2 house types, all built to 2006 Building Regulations.

While the more efficient forms of housing have a smaller levels of emissions, it may be harder to achieve a specific code level than with less efficient housing due to the way SAP and the code calculations combine (see section 7.x below).

Modifications to 2006 regulations terrace house

In this example a terraced house built to 2006 regulations is compared with one built to the thermal standards of the CAT Wates House. In both cases the effects of adding PV and SHW are modeled. This simple case shows the value of ensuring good thermal efficiency before adding renewables. The ‘Wates fabric’ terrace without renewables produces less CO2 emissions than does the 2006 regulations terrace with renewables fitted.





Modifications to 2006 regulations terrace house

7. Discussion

7.1 Criticisms of the code

The following list of criticisms and questions of the code are often given in the building press and are circulated in the industry, but are only briefly listed here as the subjects referred to are large and would need separate studies.

- The definition of zero carbon – should zero carbon refer to the boundaries of the site of the building(s) or to wider systems of the built environment and energy production (e.g. off site wind turbines).
- Time scales – is the 2016 date for zero carbon homes (2011 in Wales) overoptimistic?
- Is zero carbon the best goal to aim for? Some commentators would prefer to develop a low tech approach focussing on reliable and effective techniques of insulation, and ensuring airtightness, and efficient water heating, as opposed to the use of onsite micro-renewables to generate relatively small amount of energy. The Good Homes Alliance takes this stance (May, GBB, 4th ed, p98)
- All energy for zero carbon homes must be generated onsite - This requirement is particularly relevant when developments are small (such as a single house). This is very expensive to do, but with large scale developments technologies such as CHP can be used efficiently and cost effectively.
- Use of the inaccurate SAP method is questionable although this method is due to be updated in 2009
- Loopholes in the calculation methods mean it can be easier to achieve code levels 3 and 4 using electrical heating than by using gas heating. Producing electrical energy through non-renewable technologies emits more carbon dioxide than producing the same amount of energy through burning gas.
- Because the code scoring method compares the improvement of the DER of the proposed design with an equivalent notional design built to 2006 Building regulations standards (the TER), it can be easier to achieve improvements when the starting point is inefficient. This could mean that a thermally inefficient design of house could get a higher code rating than a house with a more efficient design and lower carbon emissions. This particular aspect requires further research.

- The ‘materials’ section of the code is arguably unambitious and does not properly reward use of healthy and low embodied energy materials. The emissions from the manufacture and transport of the materials from which the building is made are not properly accounted for.
- The ‘water’ section is currently coming under scrutiny by amongst others the Good Homes Alliance, and it seems highly likely that changes will be made here (see May et al, 2008)
- Criticism is sometimes made of the fact that the BRE run the scheme yet are a commercial organisation. This arrangement might not lead to open sharing of best practice due to commercial pressures.

7.2 Energy and emissions

This study and others has shown that the relationship between the code, SAP, renewable energy technologies and zero carbon buildings is complex and opaque. This is partly due to the use of SAP which is widely recognised as a rather poor modelling tool. This becomes particularly relevant when one considers that code levels 5 and 6 are very demanding on thermal performance and that a lot of effort is required to reach them. If this is wasted effort in environmental terms then clearly there is a problem.

There is also some scepticism in the industry as to whether the targets of the code are achievable at present, and even whether a general target of zero carbon will not be counterproductive. Taylor and Wooley (2008) point out that it may be better to build to level 4 (in terms of energy demand) and focus on doing this consistently well rather than relying on micro-generation and sophisticated but unreliable methods for achieving very low heat losses.

There are also issues to do with the emissions due to cooking and appliances. The code is trying to use generalised data with the proviso that users can contact the BRE if other technologies are to be used (or prototypes tested). This creates a problem as the BRE will probably need to be conservative in their estimates as to emissions savings, or even ignore potential savings due to lack of data.

7.3 Structure and development of the code

There are many points of discussion that can be made to do with the development of the code. It is not possible here to do much more here than suggest one or two directions of further enquiry and possibly research, as substantial work has gone into the formulation of the code and one can expect the same to be true of any future developments.

7.3.1 Experiment and innovation

It would be interesting to consider further the idea of providing credits to developers who want to try potentially useful technologies, perhaps with the proviso that they are monitored and the results published. The money required for this might be saved through not having to get so many credits in other areas for any particular code level. This would increase the diversity of solutions available at present and over time would lead to an increase in performance of the best ones. Some of the technologies will not work as well as hoped, but if the testing programme was well structured then the failures would be identified and not used again. This approach would get the code away from a box ticking mentality and towards one of genuine experimentation and innovation.

The insulated oven in the Wates house would almost certainly save cooking emissions if non-renewables are being used as the energy source. But because the increase in performance is reflected in the code score, a developer is unlikely to try anything out of this kind.

It should also be recognised that very little work has been done on how the occupant influences emissions and other environmental impacts and the control systems that are a part of this. This is another example of where experimentation and monitoring would be invaluable and the code could encourage this in the way suggested above.

7.3.2 Inter related issues

The code tends to look at single issues and then integrates all these together under the points system. One example is in water usage. Maximum water use figures are used at various code levels (see table 3) and these can be achieved by fitting low flow taps and smaller baths. It is assumed then that these physical restrictions will lead to the lower rates of water usage. Leaving aside the arguments against this outcome actually occurring (e.g. householder dislikes low flow tap and fits unrestricted model), other objections and arguments can be made here. There are arguments for introducing regional weightings within the code such as for water. There are also arguments for looking at two categories at the same time, for example water heating and water use.

If the need to conserve water was lessened in some areas (e.g. those with high rainfall), then the next issue is the emissions caused in heating the water. While it could be argued that heating up water should be minimised as a matter of course, in fact the code does not reflect this as long as zero carbon technology is used. The argument that the energy from such technology could be used better elsewhere is ignored. But that aside, it might be that a water to water heat pump could be used on the greywater from the bath, similar to the original Wates House. If this could recover even half of the heat then that would be equivalent to halving emissions from water heating. Now the inhabitants of cold and rainy locations could have deeper hot baths and longer showers, as long as the required technology was fitted and shown to work.

The success of these types of developments to the code would depend on a clear understanding of what typical household inhabitants in various regions find to be necessary and/or desirable, data on water resources around the country, and of course proper testing and studies of the technology involved. There is an unrealistic feel to parts of the code as it stands, particularly in the section on water use and how this can be achieved at higher code levels. The public as well as developers will need to support the code if it is to achieve its aims. In the case of the Wates house at CAT the occupants would have probably been sympathetic to the technology and its limitations and would have adjusted their lifestyle to a certain extent if required. The social aspects of resource use and consumerism are not well understood but research activity is turning towards these at present, as is the study of whether energy technologies in homes and elsewhere are used as intended.

The above example is only one, and it may turn out that it is unworkable or leads to greater environmental impacts, but that does not mean it should not be looked at in greater depth along with other similar examples.

8. Conclusions

Although this has been a short and selective study based mainly on the Wates House, some conclusions about the code can be made as follows;

- It would be useful to look more closely at how the code scoring system correlates to environmental impacts in each of the code categories.

- The use of SAP in its current form seems unsatisfactory but may be remedied when SAP is updated in 2009.

- It is clear that much research remains to be done on how inhabitants use their homes, and to determine what technologies will help reduce impacts and what will simply be ignored or replaced. The way water is used in the home is a good example of this.

- The structure of the code could accommodate more scope for experimentation and innovation, perhaps by rewarding developers prepared to try something new. The Wates house at CAT would never have been built without this spirit of enquiry. This approach would require a formal monitoring and reporting system to disseminate results.

- There is useful research and development to be done on how issues and indicators can be combined to better reflect adverse environmental impacts in the scoring system. The example of heat pumps used on greywater to allow fuller baths and increased use of hot water in areas of high rainfall was identified here, and will be other similar examples. This type of thinking might widen the appeal of the code as it could potentially then be seen as primarily enabling the building of comfortable well constructed homes rather than run the risk of being perceived as an arduous and expensive process leading to environments unliked by house buyers.

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Space heating system (taken from..)

Air–air heat pump - the compressor was similar in size to domestic deepfreeze, evaporator heat exchanger in roof space fed with combined kitchen extract air mixed with outside air
Warm air to all rooms via under floor space, returned via ceiling level vents
The refrigerant circuit could be reversed for defrosting and summer cooling if required. The latter has never proved to be necessary
the heat pump system was only adequate in mild weather due to heat exchanger icing and reduced COP in cold weather
a propane gas boiler was retrofitted to feed 2 radiators in house – monitoring using a heatmeter showed that in coldest weather 1kw was enough to heat the house to its design temp of 18C

In the SAP worksheet there are two scenarios for calculating energy requirements;
individual heating systems including micro-CHP
community heating

Not included in SAP – wind energy, small scale hydro, fuel cells

It is becoming an increasingly heard criticism that the code is in some way lacking in credibility due its use of SAP.

The Wates house at CAT has been modified at various times to include or update renewable technologies, but these have all been applied to the house only and are not part of a wider district scheme (in the future however the house may well be integrated into the biomass CHP and SHW district heating scheme).