



# Final report: Tarbase modelling of Park Homes

# A report for Alba Building Sciences Ltd

D. Jenkins, V. Ingram and R. Kilpatrick

Urban Energy Research Group

Heriot-Watt University

27<sup>th</sup> May 2011



# **Final report: Tarbase modelling of Park Homes**

# **1. Introduction**

The following report summarises the findings of the Tarbase modelling work for Alba Building Sciences Ltd on various Park Homes dwellings in the UK. The work has been carried out by Dr David Jenkins, Richard Kilpatrick and Vicky Ingram of the Urban Energy Research Group, at Heriot-Watt University's School of Built Environment.

A total of 100 homes were modelled as baseline buildings, with a selection of twenty of these homes refurbished with energy-saving measures. For both pre- and post -retrofit results, different metrics have been used to display the modelled results, with a focus on energy consumption, carbon emissions and fuel bills. However, where building fabric performance is being investigated, energy consumption is usually used as the metric to remove any variations due to different heating sources (which would cause variation in both carbon emissions and fuel bills, and is separately investigated).

# 2. General assumptions

Separate datasheets were provided for each of the 100 baselines buildings by Alba Building Sciences. Occasionally the values of boiler efficiency and energy tariff of the heating fuel were estimated and the following is a summary of assumptions used to model the buildings in an appropriate way.

# 2.1 Energy tariffs and carbon dioxide intensities

To calculate the energy bills and carbon emissions of the dwellings, it was necessary to estimate the energy tariff (p/kWh) and carbon dioxide intensity ( $kgCO_2/kWh$ ) of the various fuels being used

The assumed values were taken from the Government's Standard Assessment Procedure (SAP) 2009<sup>1</sup> and account for the common fuels used by Park Homes, such as bottled and tanked gas/LPG.

However, energy tariffs in particular are prone to variations, both through time and geographical location therefore, while energy bill figures were provided with the building performance data, it is suggested that the tenants are paying higher tariffs than those stated in SAP

The values used in this report are given in Table 1. Note also that standing charges and other one-off costs are not included in the energy bills presented in later sections.

		Unit price (p/kWh)	CO <sub>2</sub> intensity (kgCO <sub>2</sub> /kWh)	
	Mains gas	3.10	0.198	
	Bulk gas/LPG	5.73	0.245	
Heating fuel	Bottled gas/LPG	8.34	0.245	
Heating fuel	Coal (bags)	2.97	0.301	
	Oil	4.06	0.274	
	Wood logs	3.42	0.008	
	Mains electricty	11.46	0.52	
Off peak electricity		6.17	0.52	

Table 1- Summary of energy tariffs and CO<sub>2</sub> intensities

<sup>\*</sup>used for electric storage heating

<sup>&</sup>lt;sup>1</sup> Building Research Establishment (BRE), UK Government's Standard Assessment Procedure (SAP), 2009

### 2.2 Other assumptions

To enable modelled outputs where data was unavailable, the following assumptions have been made across the various models:

- Unless explicitly listed in the datasheets, all lighting is assumed to be incandescent at luminous efficacy of 13lm/W, which will also contribute to heating in the dwelling. The few dwellings listed as having compact fluorescent lighting (CFLs) are modelled with 55lm/W, and spotlights (assumed to be halogen) at 20lm/W. Strip lighting is assumed to be T8 fluorescent tubes at 80lm/W.
- Where sufficient data was available, the Seasonal Efficiency of Domestic Boilers in the UK (SEDBUK) website<sup>2</sup> was used to estimate seasonal boiler efficiency. If the boiler information was insufficient to identify in SEDBUK, then sensible estimates were used as detailed in Appendix I.
- If a dwelling uses secondary electrical heating (to compliment gas/oil/coal heating) this is accounted for by weighting the space heating carbon intensity and tariff as 90% main (e.g. gas) and 10% electrical. However, if electrical heating was clearly the main form of heating (e.g. with a small coal or wood stove supplementing this) then the ratio was weighted towards electricity. This does not affect the respective values used for domestic hot water. Some building specific weightings are included in Appendix I.
- From the supplied data, it was assumed that the stated boiler fuel was the main form of hot water heating, with any losses as a result of a described storage cylinder (at given size) accounted for in the calculations. If operation differed from this, e.g. using immersion (and therefore electricity) to heat water during the summer when no space heating is required, then this would change the resulting energy bill and CO<sub>2</sub> emission estimates, but would have less of an effect on the energy (kWh) results.
- Coal boilers are assumed to operate at 60% efficiency, unless stated otherwise.
- A small number of properties were rotated 45° for ease of modelling; with Tarbase set up to deal with building surfaces orientated towards N, S, E and W.

In addition, several building-specific assumptions were made, as detailed in Appendix I of this report.

# 3. Modelled baseline buildings

Each building is modelled separately and therefore has a separate input/output Tarbase sheet. However, with 100 buildings modelled, each individual output sheet cannot be listed here. Therefore, the following section will overview the energy, carbon and estimated billing results across all 100 buildings against chosen variables. For more detail on this, see accompanying database 'SummarySheet.xls', which includes other variables and building information.

# 3.1 Modelled carbon emissions by category

Figure 1 shows the modelled  $CO_2$  emissions of all 100 buildings by category of usage. It is clear that, although the buildings are within a very specific category (if compared to the rest of the domestic building stock), there is a wide variation in modelled results. Even normalising the total  $CO_2$  emissions by floor area (Figure 2) shows a large difference across all 100 dwellings. There are clearly other variables that need to be accounted for to understand the causes.

<sup>&</sup>lt;sup>2</sup> Seasonal Efficiency of Domestic Boilers in the UK, website: <u>www.sedbuk.com</u>



Figure 1 – Modelled  $CO_2$  emissions of each dwelling by energy category



Figure 2 – Modelled total CO<sub>2</sub> emissions per unit floor area of each dwelling

# 3.2 Age of dwelling

Figure 3 presents the modelled energy consumption per unit floor area by stated age of dwelling.

While a wide scatter in data is seen (and this should be expected due to other important variables affecting building energy performance), a clear trend is seen where older buildings are consuming more energy than newly built dwellings.

With a range of ages from 2 years to 42 years, this effect is quite visible. Data sources from the entire domestic building stock often show a slightly different trend, with houses built in the period from 1960-80 often having the worst performance, followed by pre-1960 houses, with new houses being most efficient.

The Park Homes results indicates that, if you look at a single category of housing type, there is far more of an intuitive trend in the energy performance of the building with age of construction however these results should not be extrapolated for other housing types.



This is further demonstrated in section 3.3.

Figure 3 – Modelled energy consumption per unit floor area against property age

#### 3.3 Wall U-value

With the wall material, and measured thermal performance (as provided by empirical U-values), varying widely across the 100 dwellings (from 0.46 to 2.32 W/m<sup>2</sup>K), it should be expected that this factor will play an important role in total building  $CO_2$  emissions.

**Figure 4**, plotting the total energy consumption per unit floor area against measured wall U-value, would suggest this is indeed the case, while not accounting for other factors such as the thermal performance of the other building elements.

Similar results could be found from plotting energy consumption or  $CO_2$  emissions against the U-value of other building elements, but it is always more likely to find a stronger trend with wall U-

value, as the external wall will usually be the greatest proportion of total building envelope area (and therefore contribute to greater thermal losses, particularly for dwellings such as Park Homes where walls are extremely thin).



Figure4 – Modelled energy consumption per unit floor area against wall U-value

Figure 5 shows the strong relationship between the measured wall U-value and the age of the property, suggesting wall U-value is likely to be the dominant factor causing the trend in Figure 3. This also suggests that the older properties require substantial fabric improvements, with some of the higher U-values likely to be exacerbated by poor maintenance and degradation of building material.



Figure 5 – Measured wall U-value against property age

#### 3.4 Infiltration rate

The infiltration rate of each home was provided from measurements. These empirical values were assumed to be indicative of operational air change (though variations would be expected due to door and window openings – some of which is accounted for in the ventilation assumptions of the Tarbase model).

The air-tightness as measured was, like other parameters, extremely variable. The modelled effect that this has on total energy consumption per unit floor area is seen in **Figure 6**.

There is a noticeable trend, where more air-tight buildings have lower energy consumptions, but this relationship is not as strong as, for example, that of wall U-value. There are several reasons for this.

Firstly, the plot shows total energy consumption, and so includes energy consumption (such as lighting and appliances) that is not connected to air-tightness.

A second, and perhaps more important, reason relates to the size of the property. Any space heating load will be due to a combination of ventilation conductance (i.e. the effect of cooler external air being exchanged with warmer internal air) and fabric heat losses

A smaller building, as investigated here, will generally have a higher envelope area to volume ratio and so it would be expected that the space heating load is more sensitive to fabric U-values than to air-change variations, and this is demonstrated in both Figures 4 and 5.



Figure 6 - Energy consumption per unit floor area against infiltration rate

#### 3.5 Heating fuel type

The above variables are just some of the factors affecting total energy consumption. However, if more concerned with carbon emissions or fuel bills, the heating fuel used becomes more important.

The data collected suggests seven different types of primary heating for each home, with some being used in conjunction with secondary heating such as wood stoves and portable electric fires.

Figure 7 shows the effect of heating type against total carbon emissions per unit floor area as modelled by Tarbase. As the *total* emissions are used as the metric (not just space heating), there is a large variation within each category, with substantial energy usage (from lighting and appliances etc) not being affected by heating fuel source.

Figure 8 is an equivalent graph but using total energy bill (per unit floor area) as the metric. The conclusion to be drawn from both these figures is that, accounting for variations caused by other parameters, mains gas provides substantial carbon and cost savings when compared to other fuel types. Both electric forms of heating (using the tariffs and figures from Table 1) perform relatively poorly for both carbon emissions and cost. Due to the high price of bottled gas/LPG, this fuel can also be related to higher energy bills, while being more towards the median in terms of carbon emissions. These conclusions are limited in that each category is populated with a different number of dwellings (e.g. electric heating as a primary source is much less common than the various forms of gas heating), but the modelled output does imply a trend in both carbon emissions and cost, suggesting types of heating that should be avoided where possible.



Figure 7 – Modelled total CO<sub>2</sub> emissions per unit floor area across all heating fuel categories



Figure 8 - Modelled total energy bills per unit floor area across all heating fuel categories

### 3.6 Summary of pre-retrofit modelling

This assessment of the baseline dwellings can be used to identify sensible refurbishment options, and the likely factors causing high energy consumption, carbon emissions and fuel bills in the identified homes. Such an approach is suggested as a sensible initial stage prior to making changes to buildings that might accrue substantial capital costs.

It is clear that wall U-value and, related to this, property age are of a concern in many of the dwellings. Additionally, many properties (often due to external circumstances, such as being off the gas grid) are using heating fuels that are high in both carbon emissions and energy tariffs. The combination of these factors results in inefficient buildings being heated by inefficient fuels, which is likely to increase the fuel poverty rate of these properties dramatically.

While cost-effective measures, such as draughtproofing, would be recommended, it is clear that higher capital cost measures would be required to make more substantial savings in both energy bills and carbon emissions. These might include insulation to floors, roofs and external walls with an external render finish likely to be most viable for these dwellings.

The next step of this study will estimate the likely savings of such measures for a selection of dwellings based on actual measurements of refurbishment data, accompanied by additional calculations through the Tarbase model.

# 4. Modelled retrofit improvements

The results of twenty retrofit improvements, carried out for a selection of the Park Homes buildings, were modelled using the same method documented in sections 2 and 3, i.e. using the Tarbase model. The existing baseline models were accessed and, using a facility within the model, specific fabric improvements were applied as measured by Alba Building Sciences.

# 4.1 Building fabric refurbishments

Pre and post improvement U-values and measured change in infiltration rate are given in Table 2

	PRE-IMPROVEMENT			NT	POST-IMPROVEMENT		% reduction					
	U-val	ues (W/	/m2K)	Inf.	U-va	ues (W/	′m2K)	Inf.	U-va	alues (W/m2K)		Inf.
				rate				rate				rate
Code	Wall	Roof	Floor	AC/h	Wall	Roof	Floor	AC/h	Wall	Roof	Floor	AC/h
AP 31	1.14	0.96	0.83	0.78	0.35	0.96	0.45	0.52	69	0	45	33
AP 32	0.62	0.44	0.42	0.56	0.20	0.29	0.35	0.31	67	33	17	45
AP33	1.27	0.76	0.78	0.74	0.33	0.76	0.25	0.56	74	0	69	24
AP 34	1.15	0.43	0.76	0.62	0.32	0.30	0.33	0.42	72	30	57	32
AP 35	0.88	0.51	0.62	0.68	0.31	0.51	0.36	0.47	65	0	42	31
AP 36	0.78	0.34	0.83	0.58	0.29	0.21	0.32	0.36	62	37	62	38
AP 37	1.39	0.84	1.21	0.59	0.30	0.23	0.39	0.38	78	72	68	36
AP 38	0.70	0.56	0.54	0.47	0.26	0.31	0.33	0.29	64	45	38	38
AP 39	0.70	0.51	0.59	0.68	0.37	0.28	0.34	0.41	47	46	43	40
AP 40	0.70	0.48	0.32	0.60	0.23	0.21	0.22	0.39	67	57	31	35
AP 41	0.74	0.46	0.69	0.55	0.29	0.20	0.25	0.26	60	56	65	53
AP 42	1.61	1.32	0.57	0.84	0.35	0.34	0.24	0.54	78	74	58	36
AP 43	1.01	0.84	0.99	0.47	0.26	0.28	0.21	0.29	75	67	79	38
AP 44	0.88	1.43	0.74	0.51	0.33	0.36	0.23	0.36	63	75	68	29
AP 45	1.14	0.92	0.85	0.77	0.24	0.25	0.32	0.44	79	72	62	43
AP 46	0.80	0.45	0.42	0.46	0.26	0.24	0.25	0.29	67	46	39	37
AP 47	0.51	0.49	0.48	0.37	0.19	0.16	0.15	0.22	64	67	69	41
AP 48	0.46	0.41	0.40	0.38	0.17	0.18	0.18	0.23	62	57	54	39
AP 49	1.57	1.41	0.76	0.89	0.33	0.35	0.40	0.47	79	75	48	47
AP 50	0.71	0.51	0.47	0.69	0.26	0.51	0.21	0.44	63	0	56	36

Table 2 – Measured change of U-value and infiltration rates of twenty Park Homes

There were therefore essentially four refurbishment options: wall insulation, roof insulation, floor insulation and draughtproofing (some of the latter being linked to the other measures, but for the sake of calculation will be considered as a separate measure).

All but four of the dwellings are subject to all of these improvements, with AP31, AP33, AP35 and AP50 not having the roof insulation measure.

The overall energy and carbon savings (from all measures) will be documented for all the homes in this section, with calculated step-by-step effects of the measures given for chosen dwellings (and also displayed in Appendix II).

#### 4.2 Total CO<sub>2</sub> emissions for refurbished dwellings

Figure 9 is for comparison with Figure 1, with all the listed refurbishments (quantified by the U-value and air-change improvements of Table 2) applied to each dwelling.



Figure 9 – Modelled CO<sub>2</sub> emissions of each dwelling by energy category after refurbishments

Due to the nature of the chosen refurbishments, the savings are predominately for space heating, though there is a small saving in the appliance category as the electrical consumption of a boiler pump (which will be reduced after the measures) is included in this category.

It is noticeable that, where previously space heating carbon emissions were generally greater than 50% of the total emissions (Figure 1), they are now less significant as a percentage of the total.

For some dwellings the space heating carbon emissions are less than 10% of the total, though at such low predicted values building models are likely to have a high margin for error (as rebound or "take-back" effects become more important, with occupants heating their homes to higher temperatures than they were prior to the refurbishment).

### 4.3 CO<sub>2</sub> savings compared to baseline dwellings

Comparing the results of Figures 1 and 9 produces Figure 10.

In blue, the estimated  $CO_2$  savings of each dwelling is shown compared to the total baseline  $CO_2$  emissions. The average reduction is 24%, ranging between 15% and 38%.

In red the reduction in space heating only is shown, where the vast majority of the saving is being made.

When just looking at this category, an average saving of 60% is estimated, ranging between 34% and 85%.



Figure 10 – Modelled CO<sub>2</sub> savings of dwellings compared to baseline

As already mentioned, these very large savings might not be realised in practice due to changes in occupant behaviour – and such behaviour changes can only accurately be investigated by monitoring internal temperatures before and after refurbishment.

However, the results are illustrative of the relative change in effect of the different refurbishments from one dwelling to another (e.g. explaining why the space heating saving for AP35 is less than half that of AP43). To further explore this, the next section will distinguish between the refurbished dwellings to estimate the effect of refurbishment variables on potential carbon savings.

# 4.4 Variables effecting carbon saving potential

Prior to this analysis, it is important to emphasise that twenty refurbished dwellings provide a limited statistical sample against which very general conclusions are drawn about the effect of the insulation improvements to any dwelling.

However, the output is backed by the measured building data and modelled results, and could therefore be used to suggest the direction of future refurbishment programmes.



Figure 11 – Modelled post-retrofit energy consumption per unit floor area against property age



Figure 12 – Modelled post-retrofit energy saving (%) against property age

Figure 11 shows the total post-retrofit energy consumption (kWh/m<sup>2</sup>) of the twenty dwellings. A broadly similar trend to Figure 3 is seen, that is the older properties are still consuming more energy than the more recently built ones. This suggests that the measures chosen for each property were not completely dependent on the state of the property, i.e. the "worse" properties did not get more effective refurbishments than the newer properties. In support of this, Figure 12 suggests that the *relative* effect of refurbishments is not dependent on property age. Based on this metric, the refurbishment programme is therefore predicted to be, approximately, of similar value to properties of all ages.

#### 4.5 Step-by-step effect of different refurbishments

The refurbishments of each dwelling were modelled individually to obtain step-by-step estimates of their effects. For simplicity, the results for just two homes will be shown here, but graphs for all twenty are produced in Appendix II for comparison, with all savings cumulative. For this analysis, all dwelling refurbishments are modelled in the order of: wall insulation, roof insulation, floor insulation and air-tightness improvements. This is broadly in order of expected improvement (largest first), with air-tightness being the result of all measures and therefore logically the final modelled step.

Figure 10 suggests that the dwelling with the smallest reduction to space heating after all measures will be AP35, with a reduction of 34% (see Figure 13). This is unsurprising as this building did not undergo the roof insulation refurbishment, the roof U-value staying at  $0.51W/m^2K$  (significantly higher than the roofs of the refurbished dwellings). The wall insulation measure, as modelled, produced a 13% reduction in total CO<sub>2</sub> emissions, which equates to a 24% reduction in space heating. The additional space heating reduction due to floor insulation (6%) and reduced air-change rate (8%) is more modest – though a more significant saving might be ascribed to these measures if they had been carried out first (remembering that the calculated carbon savings are cumulative).



Figure 13 – Step-by-step carbon savings for refurbished Park Home AP35

This lower impact is partly due to heat loss through walls, particularly for a small dwelling, having more of an impact on space heating than other building elements due to the larger surface area. Also, the magnitude of improvement of these measures was less when compared to baseline values (see Table 2).

The dwelling with the largest predicted space heating saving is AP43, with a reduction of 85%. As discussed in section 4.3, this large value is very dependent on changes in user behaviour but it does suggest a dramatic improvement to the baseline dwelling would be expected. The wall insulation measure, as shown in Figure 14, reduces space heating by 43%. Roof insulation produces an additional saving of 41%, floor insulation a saving of 16% and improved air-tightness 17% (all compared to the previous step). With the pre-retrofit building being particularly poor from an energy saving point of view, and the percentage improvements from the four measures being towards the upper end of all homes measured, then these high predicted savings are to be expected. However, Figure 9 suggests that amongst the twenty post-retrofit dwellings, the total carbon emissions of AP43 is still towards the upper end (seventh highest), partly due to high predicted appliance usage.



Figure 14 – Step-by-step carbon savings for refurbished Park Home AP43

#### 4.6 Relative effect of refurbishments on total savings

To compare the relative effect of the four different measures on the total carbon saving, a simple regression analysis was carried out comparing measured improvements to building fabric (namely percentage improvement of U-values in wall, floor and roof, and infiltration rate – see Table 2) to the reduction in space heating calculated by Tarbase.

The result of this analysis is a simple equation suggesting the space heating reduction that might be expected from given improvements in building fabric, for Park Home dwellings. Equation 1 gives the resulting relationship.

$$\left(\frac{\Delta E}{E}\right)_{\%} = 0.28 \cdot \left(\frac{\Delta U_{w}}{U_{w}}\right)_{\%} + 0.37 \cdot \left(\frac{\Delta U_{r}}{U_{r}}\right)_{\%} + 0.30 \cdot \left(\frac{\Delta U_{f}}{U_{f}}\right)_{\%} + 0.22 \cdot \left(\frac{\Delta ACH}{ACH}\right)_{\%}$$
(Eq.1)

where the first term in brackets on the left-hand side of the equation is the percentage reduction in space heating energy consumption and the four terms on the right-hand side relate to the percentage reduction of the wall, roof and floor U-values ( $U_w$ ,  $U_r$ , and  $U_f$ ) and percentage reduction in air changes per hour (ACH). The numbers in front of these four terms are the regression coefficients – these are an indication of the "importance" of each term in producing the modelled space heating energy saving. They are found by optimising the results of Equation 1 with that of the Tarbase model.

This expression is not suitable for generic application to all buildings – it is simply constructed from comparing the measured improvements in the building with the resulting Tarbase predictions for space heating. Figure 15 demonstrates the results of using Equation 1 with the prediction from the Tarbase model.



Figure 15 – Comparison of Tarbase results with regression formula for predicting space heating reduction

There is a small difference between the results of Equation 1 and the Tarbase model but a reasonable agreement is seen. One important reason for the difference is that space heating consumption is directly related to *net* heat loss, not gross heat loss; that is, it is important to know the heat gain within the building as well as the heat loss. While the Tarbase model accommodates the difference in heat gains from dwelling to dwelling, equation 1 doesn't and is therefore meant only as a rough guideline for the small sample of retrofitted dwellings studied. Furthermore, the validity of the equation for U-value reductions at a magnitude outside those used in the Park Homes study is unknown. However, the regression analysis suggests that all four terms are influential in

producing the total space heating saving predicted by the Tarbase model, as the regression coefficients are of a similar value for all four refurbishment terms. Also, if a first order approximation of space heating savings was required (as opposed to a full Tarbase modelling exercise), this equation could be used for other Park Homes by inputting percentage reductions in the four chosen refurbishment measures. For example, if another home had U-values of wall, roof and floor reduced by 25%, 40%, and 30% respectively, and infiltration rate reduced by 50%, then the space heating savings would be calculated as:

$$\left(\frac{\Delta E}{E}\right)_{\%} = (0.28 \times 25) + (0.37 \times 40) + (0.30 \times 30) + (0.22 \times 50)$$

Therefore these measures, if the weighting of their effects were similar to the Park Homes analysed, might reduce space heating by nearly 42% in combination. If the home had significantly different internal heat gains, construction, location or size however, it is unlikely this relationship would still hold and a full Tarbase modelling exercise should be carried out.

#### 4.7 Using trends for future refurbishment projects

In addition to the above trend analysis, this modelling work is intended to inform decisions for further projects for Park Homes-type dwellings.

Table 3 – Overview of space heating savings for refurbished Park Homes (Red = minimum in category; Blue = maximum)

Category of	Park	% reduction in	Average for		
building	home	space heating	that category		
	AP 33	42			
1970, Blue Flag	AP 34	52	53.3		
	AP 37	66			
	AP 42	76			
1070 Devecel	AP 43	85	77 5		
1970, Parasoi	AP 45	84	//.5		
	AP 49	65			
	AP 31	39			
	AP 35	34			
1091 Plue Fleg	AP 36	50			
1901, Diue Flag	AP 38	47	44.5		
	AP 39	45			
	AP 40	52			
1091 Darasal	AP 44	79	65.0		
1901, Parasor	AP 50	51			
1995, Blue Flag	AP 32	47	47.0		
	AP 41	71			
1005 Darasal	AP 46	82	70.0		
1995, Parasor	AP 47	67	70.0		
	AP 48	60			

The twenty refurbished Park Homes of this study underwent two different types of treatment, namely "Blue Flag" and "Parasol", relating to the materials and manufacturers used. These are

shown in Table 3, along with estimated savings from the Tarbase model. Each home has also been categorised based on the building age, split into different ages & revisions of the BS Standard.

Based on the sample size, if we compare these savings, for the Blue Flag and Parasol categories, Figures 16 and 17 are produced. These figures show average space heating savings for each category, with minimum and maximum savings producing the "error bars". The "Parasol" treatment is a more complete set of measures so produces larger reductions in space heating, as modelled. It is noticeable that, even for this small sample, the same pattern is seen for both Parasol and Blue Flag; 1970-era buildings have the greatest potential for improvement (as would be expected as the baseline is worse) but the difference between 1981 and 1995-era buildings is small, with 1995-era buildings actually showing slightly higher savings than 1981 (though the sample size is small )



Figure 16 - Space heating savings modelled for "Blue Flag" treated homes



#### Figure 17 – Space heating savings modelled for "Parasol" treated homes

Only the reduction in space heating is given in these graphs. This is because total carbon emission savings can change significantly depending on the electrical usage (from appliances and consumer electronics) of the pre-retrofit dwelling – which varies considerably and is difficult to standardise.

Figures 16 and 17 provide an indication of the savings that the occupants might expect based on these modelled results. For example, a 1970-era home that undergoes a Parasol refurbishment might expect to see a space heating reduction of 42 to 66% - subject to the caveats already given in this report. Such significant savings could be used to justify the capital costs of this type of refurbishment, and more monitoring data from these projects will further the understanding of how occupants might react to such changes.

# **5. Final Conclusions**

A modelling study of 100 homes was carried out for a specific housing type, namely Park Homes, by the Urban Energy Research Group at Heriot-Watt University.

These 100 homes were individually modelled using the Tarbase model to ascertain their likely baseline energy consumptions and carbon emissions, categorised into appliance, lighting, refrigeration, space heating and hot water usage.

Construction details and thermal properties were based on actual measurements of the buildings (including dimensions, U-values and air-change rate) and an itinerary of internal appliances was collated for each home to provide more accuracy to the estimation of both appliance energy consumption and internal heat gains. All of this in-situ data was provided by Alba Building Sciences.

Several trends were identified in the baseline, with older buildings being significantly less energy efficient than more modern Park Homes due to a clear relationship between property age and

measured U-value of the construction elements. It was more difficult to discern a relationship between property age and infiltration rate.

Data was then collected from twenty of the homes that had been refurbished with a combination of wall, roof and floor insulation, along with associated draughtproofing measures. The Tarbase model was then used to estimate the possible effect of these changes, again based on measured U-value and infiltration rate data.

With the improvements being substantial in magnitude, significant energy savings were estimated; total carbon savings (including appliance energy consumption) were estimated to reduce by between 15 and 38% as a result of space heating reduction of between 34 and 85%.

These values should, however, be used with qualification as Tarbase is only a steady-state model and, like all such models, has limitations. Furthermore, the effect of an occupant heating their home to a higher temperature after the refurbishments have been applied has not been factored-in.

In reality the baseline data suggested that some of the occupants were probably not heating their homes to the 21.5°C temperature often used in these studies. This is likely to be due to a combination of expensive heating fuels (e.g. electricity and bottled gas), poor condition of property prior to refurbishments and income of the occupants.

The conclusions provide justification for further Park Home-improvement projects undergoing the type of refurbishment assessed in this study.

# **Contact details**

This report is a result of modelling by Heriot-Watt University's Urban Energy Research Group for Alba Building Sciences. For more information please contact:

Dr David Jenkins, Urban Energy Research Group, School of Built Environment, Heriot-Watt University, Edinburgh EH14 4AS,

Email: D.P.Jenkins@hw.ac.uk Tel: 0131 451 4637 www.tarbase.com

# Appendix I – Building specific assumptions/queries

AP1 – Exact boiler not found, Bermuda Inset 3 50/5 used, efficiency 77%

AP5 – G-rated boiler at 65% efficiency assumed

AP7 – Coal boiler not found in database, 60% efficiency assumed for manual feed coal boiler (as per SAP)

AP10 – Conflicting internal/external dimensions given. Internal dimensions estimated from external values instead.

AP11 – Insufficient boiler details given, assumed to be 78% based on likely boiler

AP14 – Insufficient boiler details given, assumed to be 75% based on likely boiler. Note: Very low infiltration rate given (0.19ac/h)

AP15 – Insufficient boiler details given, assumed to be 65% based on likely boiler

- AP16 Insufficient boiler details given, assumed to be 67% based on likely boiler
- AP17 Insufficient boiler details given, assumed to be 65% with storage based on likely boiler

AP19 – Boiler based on SAP guidance as model not present in SEDBUK

AP20 – Adjustment made to allow for two showers: one gas, one electric

AP24 – Use of immersion unclear

AP25 – 10% wood used towards space heating

AP26 – Space heating weighted for 90% coal and 10% wood. Use of immersion unclear

AP31 – Glazing U-value weighted to account for mixture of double and single glazing

AP37 – "Thin" double glazing assumed (U-value of 3.1W/m<sup>2</sup>K)

AP38 – Boiler efficiency not found, 75% assumed

AP42 – Insufficient boiler details given, assumed to be 86.8% based on likely boiler (with back-up oil heaters)

AP43 – Oil boiler assumed to have 75% efficiency

AP53 – Coal usage assumed at 30% space heating (70% electrical), with electric domestic hot water (as coal appeared to be used more than typical "secondary" heating ratio of 10%)

AP59 – Boiler data not given but, as less than two years old, 90% efficiency assumed

AP68 – Type of Worcester boiler not given, older version at 70% efficiency assumed

All  $O_{i} = 1$  ype of workester boller not given, older version at 70% enclosed assumed

AP80 – Mixture of electric storage (90%) and conventional electric radiators (10%)

AP81 and AP82 – Oil boiler assumed to have 65% efficiency

AP84 – Boiler assumed to have 92.3% efficiency

AP94 – Incomplete boiler information given, Halstead Combi HE assumed at 90.2% efficiency





Figure A – Park Home AP31 (Note: no roof insulation measure applied)



Figure B – Park Home AP32



Figure C - Park Home AP33 (Note: no roof insulation measure applied)



Figure D – Park Home AP34



Figure E – Park Home AP35 (Note: no roof insulation measure applied)



Figure F – Park Home AP36



Figure G – Park Home AP37



Figure H – Park Home AP38



Figure I – Park Home AP39



Figure J – Park Home AP40



Figure K – Park Home AP41



Figure L – Park Home AP42



Figure M – Park Home AP43



Figure N – Park Home AP44



Figure 0 – Park Home AP45



Figure P – Park Home AP46



Figure Q – Park Home AP47



Figure R – Park Home AP48



Figure S – Park Home AP49



Figure T – Park Home AP50 (Note: no roof insulation measure applied)