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CERT DEMONSTRATION ACTION INSULATION IMPROVEMENTS TO RESIDENTIAL PARK HOMES

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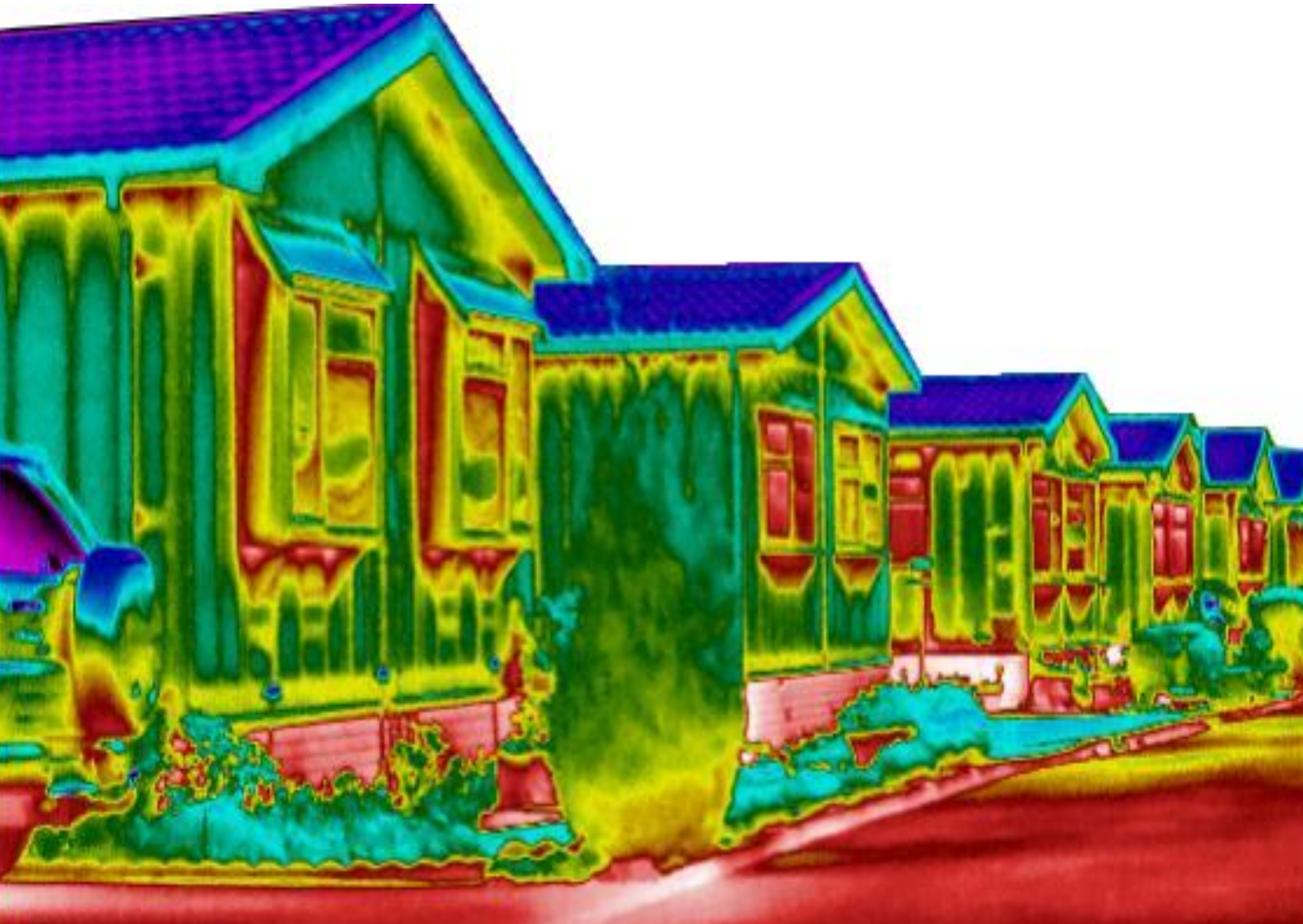

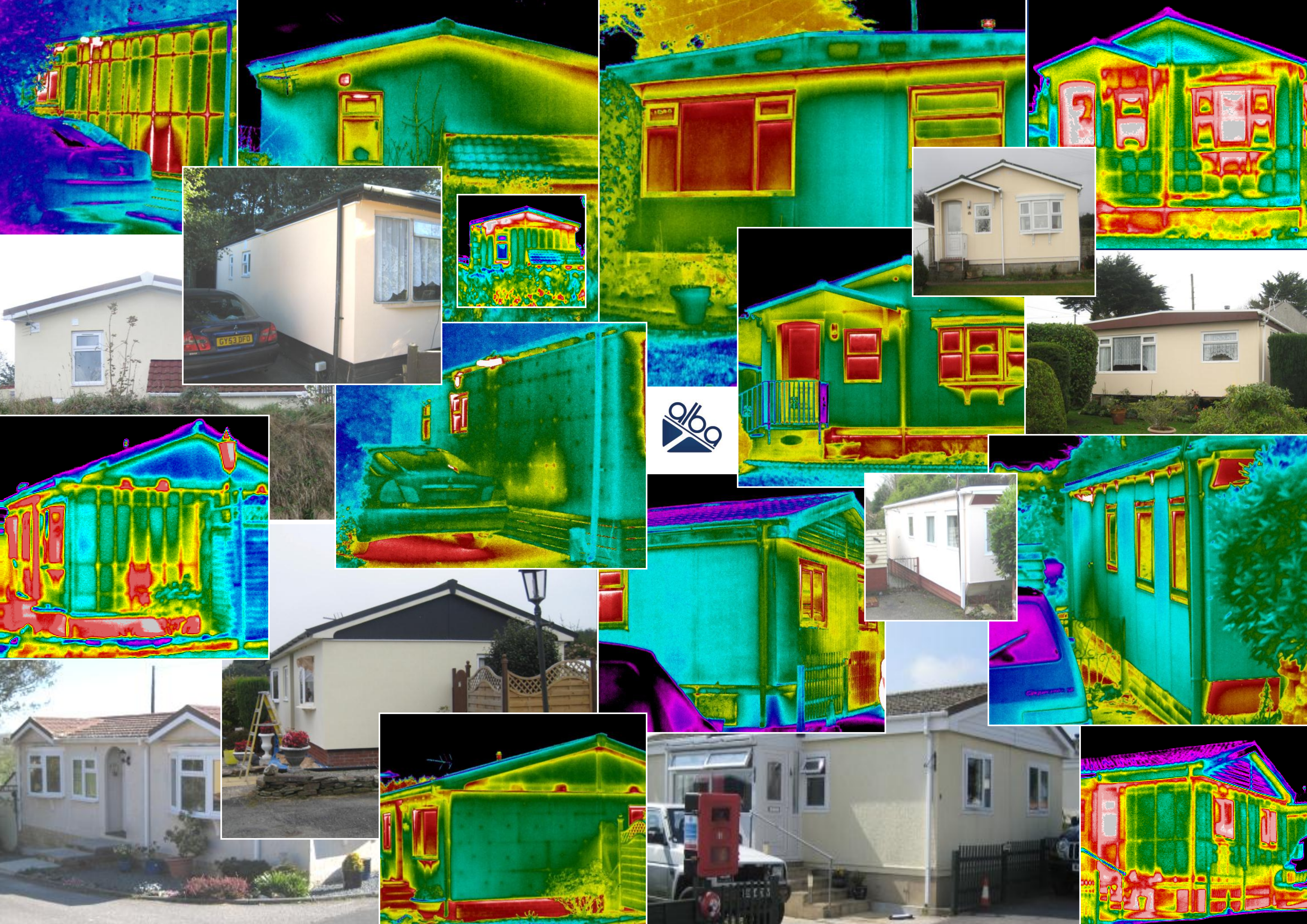
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Alba Building Sciences Ltd

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Alba Report 21050

CERT DEMONSTRATION ACTION INSULATION IMPROVEMENTS TO RESIDENTIAL PARK HOMES

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Executive Summary

There are several thousand Park Homes spread across all regions of the UK, a significant number of which are providing permanent living accommodation to families and elderly individuals, many of who are in receipt of "qualifying benefits" and at risk from fuel poverty.

The construction specifications and thermal insulation standards for the fabric of Park Homes, including those built to the latest BS 3632 2005 standard, provide for relatively poor levels of thermal insulation when compared to typical domestic dwellings and these low energy efficiency standards result in high space heating costs and CO2 emission levels.

It was believed that the addition of insulation to the external walls, roofs and under-floors of existing Park Homes would deliver a meaningful reduction in carbon emissions however there was no data base that would allow the carbon emission reduction, appropriate to each of the defined categories of Park Homes (i.e. by construction & heating fuel type), to be established

The Carbon Emissions Reduction Target (CERT) 2008 – 2011 scheme includes a 'Demonstration Action' for measures which *"are reasonably expected to achieve a reduction in carbon emissions, but for which a firm carbon emission reduction has not yet been evaluated"* and this project was undertaken by Scottish & Southern Energy plc. to develop solutions for improvement of the energy efficiency of Park Homes and to produce an accurate data set for the resultant CO2 reductions based on output from the TARBASE calculation model.

An initial step in the Demonstration Action involved a pilot project where insulation improvements to a number of Park Homes were undertaken at a site in Nottingham. The data obtained from this pilot assisted in the selection of the most suitable refurbishment "mix" of insulation for the floors, walls and roofs taking into account the practicalities of installation, the resultant thermal insulation performance benefits and value for money. Monitoring of both "pre and post–improvement" energy consumption and lifestyle influences was also undertaken over a 12 month period, as part of this pilot exercise.

Information relating to the Nottingham pilot project is provided in **Appendix 1** of this report.

The next stage in the Demonstration Action process was to undertake a scientific thermal insulation performance assessment "pre-improvement" of a representative sample mix of 100 existing Park Homes, (designated AP 1 – AP 100) sited at various locations across the UK.

In addition to thermography, air change rate and dynamic in-situ U-value performance measurements, historical data on the energy consumption of these 100 homes together with details of energy usage and occupier lifestyle influences was collated and used to inform the project.

The performance data relating to the 100 home "pre-improvement" assessments was then input into the TARBASE calculation model in order to establish categories for the various types of Park Home and to determine the space heating and CO2 emission levels attributable to each.

The results of this 100 home "pre-improvement" assessment can be found in **Appendix 2 & 2A.**

When assessing the thermal insulation performance of the 100 test homes, a direct correlation was established between CO2 emission levels and the age of a Park Home, the air permeability of the envelope, and the relevant BS Standard 3632 to which it was constructed.

The BS3632 standard was revised in 1981, 1989, 1995 and most recently in 2005 as per **Table 2 on page 8**.

Those park homes manufactured to BS 3632:1970 were poorest in terms of the pre-improvement thermal insulation performance of the envelope and incremental improvements in performance were established for those homes built to each of the subsequent revisions to the BS 3632 standard.

Following analysis of the “pre-improvement” assessment data of the 100 Park Homes, two groups of 10 homes were selected, on the basis that they provided a representative sample of UK Park Home stock, to which two different types of external wall insulation systems, Blue Flag and Paraclad, were to be installed across the envelope, in addition to insulation of the under-floors and roofs.

On completion of the insulation improvements, the two groups of ten homes were subjected to a “post-improvement” performance assessment by repeating the scientific techniques used for the “pre-improvement” measurements.

The performance data relating to the post-improvement assessments was then input into TARBASE in order to establish the carbon emission levels applicable across the various categories of Park Home contained within the two groups of 10.

The results of the 20 Home “post-improvement” assessments can be found in **Appendix 3A & 3B.**

Having established the “pre” and “post-improvement” performance of each of the 20 Homes it was then possible to compare these TARBASE results in order to quantify the level of carbon emission reduction that had been achieved by the action, appropriate to each of the defined categories and to attribute the carbon emission savings from the insulation measures.

This follows the approach and method for typical house types and heating systems / fuels in CERT and details of the comparisons in performance levels are provided in **Appendix 4, 4A & 4B.**

The TARBASE comparisons show that a significant reduction in space heating and energy usage has been delivered “post-improvement” across all the 20 Park Homes and that the Blue Flag and Paraclad insulation systems deliver meaningful benefits as tabulated in **Table 1 on page 3**.

A comparison was also run between standard SAP 2005 and TARBASE which shows that the resultant CO2 predicted outputs are quite well matched although SAP is higher, and the details of the SAP versus TARBASE comparison can be found in **Appendix 5**.

An analysis of the savings applicable across the various categories of Park Home, has shown that the Blue Flag system delivered an average reduction in space heating of 46% which equate to annual savings in CO2 emission levels of between 0.54 to 1.31 tonnes and lifetime saving (30 years) of between 16.2 and 39.3 tonnes CO2.

An analysis of the savings applicable across the various categories of Park Home, has shown that the Paraclad system delivered an average reduction in space heating of 64% which equate to annual savings in CO2 emission levels of between 0.55 to 0.96 tonnes and lifetime saving (30 years) of between 16.5 and 28.8 tonnes CO2.

Monitoring of actual energy usage and occupier lifestyle influences over the winter period, has confirmed the magnitude of the cost and energy savings being realised as shown on **Pages 4 & 5**.

The Demonstration Action has established that a significant reduction in carbon emissions would result from implementation of insulation improvement measures across all categories of UK Residential Park Homes by way of the Blue Flag or Paraclad systems.

Table 1 : Reduction in Space Heating & Energy Usage

BS Standard	Reference		U-Value W/m²K			ACH	KgCO2/m2	t/CO2/yr.	Space Heating Reduction % kWh/ m2
			Wall	Floor	Roof				
BS 3632: 1970	BS 3632: 1970		1.700	1.700	1.700	-	-	-	-
	Alba Measured 100 (Average)		1.890	1.405	1.083	0.82	97.70	3.27	-
	Blue Flag	Pre	1.272	0.919	0.680	0.65	69.70	4.43	-
	Blue Flag	Post	0.317	0.320	0.433	0.45	50.80	3.12	53 %
	Paraclad	Pre	1.332	0.793	1.121	0.74	70.25	3.06	-
	Paraclad	Post	0.293	0.290	0.306	0.44	53.31	2.10	78 %
BS 3632: 1981 & BS 3632: 1989	BS 3632: 1981 / 1989		1.000	1.000	0.600	-	-	-	-
	Alba Measured 100 (Average)		1.406	1.079	1.005	0.70	89.40	3.218	-
	Blue Flag	Pre	0.817	0.623	0.560	0.63	70.47	3.18	-
	Blue Flag	Post	0.302	0.338	0.413	0.41	55.87	2.52	45 %
	Paraclad	Pre	0.797	0.605	0.970	0.74	59.51	2.90	-
	Paraclad	Post	0.296	0.222	0.435	0.40	47.68	2.35	65 %
BS 3632: 1995	BS 3632: 1995		0.600	0.600	0.400	-	-	-	-
	Alba Measured 100 (Average)		0.900	0.768	0.690	0.58	70.00	3.144	-
	Blue Flag	Pre	0.624	0.421	0.437	0.56	43.40	2.60	-
	Blue Flag	Post	0.204	0.350	0.291	0.31	31.48	2.06	47 %
	Paraclad	Pre	0.629	0.495	0.450	0.44	47.04	3.28	-
	Paraclad	Post	0.229	0.206	0.196	0.25	37.39	2.60	70%
BS 3632: 2005	BS 3632: 2005		0.500	0.500	0.350	-	-	-	-
	Alba Measured 100 (Average)		0.680	0.384	0.635	0.31	65.28	3.00	
	Blue Flag	Pre	0.680	0.384	0.635	0.31	65.28	3.00	
	Blue Flag	Post	0.238	0.268	0.540	0.25	54.57	2.37	39%
	Paraclad	Pre	0.680	0.384	0.635	0.31	65.28	3.00	
	Paraclad	Post	0.272	0.177	0.292	0.18	50.20	2.18	44%

Blue Flag – Actual Energy Costs Pre v Post Improvement

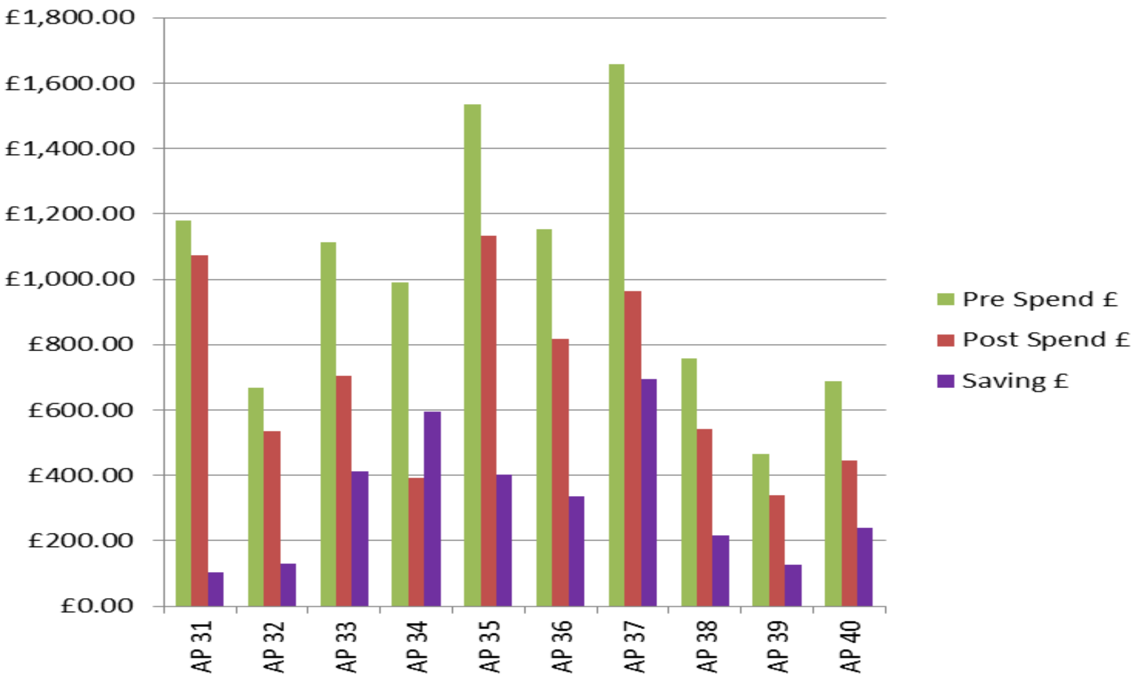
The audit of actual costs "post-improvement" confirmed that significant savings were being realised across the group of 10 homes insulated with the Blue Flag system. A reduction in fuel usage was accompanied by reduced expenditure on space heating and on electric energy consumption. A synopsis of the savings applicable to each home is presented below and a full analysis **provided in Appendix 6.**

Blue Flag: Summary Average Savings Pre v Post Improvement.

Blue Flag AP 31 - 40	Average Savings (Pre v Post Improvement)	
	£ Cost Saving as %	**Consumption Saving as %**
Heating / Fuel	35 %	39 %
Electricity	12 %	11 %
An average combined Heat & Power £ cost saving of 31 %		

Blue Flag: Combined Energy (Heat & Power) Costs "Pre v Post-Improvement"

REF	Combined Actual Cost Pre Improvement	Combined Actual Cost Post Improvement	Combined Cost Saving	
	Nov 09 - May 10	Nov 10 - May 2011	£	%
AP 31	£1,179.89	£1,074.69	£105	9%
AP 32	£668.20	£536.76	£131	20%
AP 33	£1,114.53	£703.21	£411	37%
AP 34	£988.65	£392.66	£596	60%
AP 35	£1,534.22	£1,132.80	£401	26%
AP 36	£1,152.19	£817.66	£335	29%
AP 37	£1,657.00	£963.22	£694	42%
AP 38	£758.33	£541.19	£217	29%
AP 39	£465.94	£338.45	£127	27%
AP 40	£688.00	£447.18	£241	35%



Paraclad – Actual Energy Costs Pre v Post Improvement

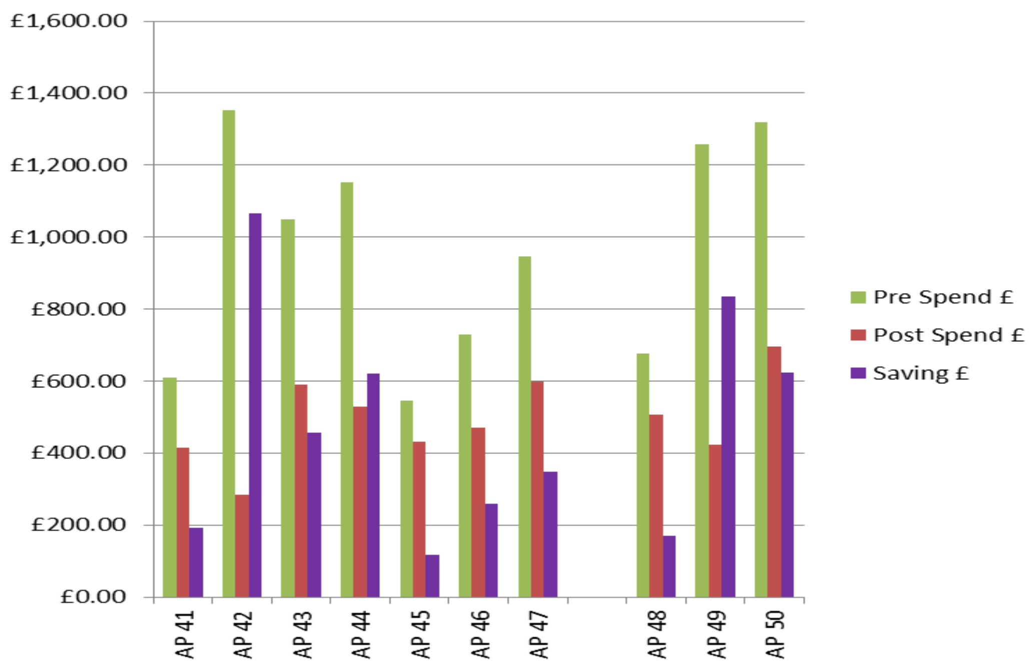
The audit of actual costs "post-improvement" confirmed that significant savings were being realised across the group of 10 homes insulated with the Paraclad system. A reduction in fuel usage was accompanied by reduced expenditure on space heating and on electric energy consumption. A synopsis of the savings applicable to each home is presented below and a full analysis **provided in Appendix 6.**

Paraclad: Summary Average Savings Pre v Post Improvement.

Paraclad AP 41 - 50	Average Savings (Pre v Post Improvement)	
	£ Cost Saving as %	Consumption Saving as %
Heating / Fuel	53 %	54 %
Electricity	11 %	12 %
An average combined Heat & Power £ cost saving of 44 %		

Paraclad: Combined Energy (Heat & Power) Costs "Pre v Post-Improvement"

REF	Combined Actual Cost Pre Improvement	Combined Actual Cost Post Improvement	Combined Cost Saving	
	Nov 09 - May 10	Nov 10 - May 2011	£	%
AP 41	£608.66	£415.70	£193	32%
AP 42	£1,351.60	£284.68	£1,067	79%
AP 43	£1,048.41	£590.59	£458	44%
AP 44	£1,152.00	£530.00	£622	54%
AP 45	£546.95	£430.96	£116	21%
AP 46	£728.54	£469.92	£259	35%
AP 47	£945.40	£598.65	£347	37%
AP 48	£676.47	£505.83	£171	25%
AP 49	£1,257.98	£423.48	£835	66%
AP 50	£1,319.29	£694.73	£625	47%



Background on CERT

“The Carbon Emissions Reduction Target (CERT) 2008 – 2011 (which follows on from the Energy Efficiency Commitment (EEC) 2005 – 2008) requires gas and electricity suppliers to achieve targets for a reduction in carbon emissions generated by the domestic sector.

The programme is known as the CERT and the target for carbon emissions reduction as the CERT target. Each supplier has an individual target, known as its 'carbon obligation'.

In addition to standard submissions to promote measures that can be attributed with a carbon emissions reduction, suppliers may submit demonstration actions, which are measures to which a firm quantified carbon emission reduction cannot yet be attributed.

“Demonstration Action” is defined in the Statutory Instrument for CERT as ‘an action which is reasonably expected to achieve a reduction in carbon emissions’.

As demonstration actions do not have a determined carbon emission reduction, the carbon emissions reduction attributed to a supplier for undertaking these actions is dependent on the cost of the activity.

In addition, OFGEM may not approve a demonstration action unless the information provided in the notification of the action, including costs, is reasonable, and the supplier consents to the publication of the information relating to the monitoring and assessment of the action.

Activity to trial a technology would seek to determine whether the product does lead to a reduction in carbon emissions under normal operating conditions in the domestic environment.

Where possible, the results from these trials should be normalised against the standard measures in this programme, taking account of such factors as external temperature variation, heating season, hours of use, property type and occupation pattern etc.

This will ensure that the energy saving can be attributed to the impact of the measure being trialled and not to other factors.

The methodology to be adopted in this demonstration action is in line with how standard measures in the CERT programme have been and will continue to be assessed.

The focus of any demonstration action should be on providing a robust and useful assessment of the impact of the activity carried out. The carbon emissions reduction is then dependent on the cost of the action, not on the actual carbon emissions reduction achieved by the activity”.

Introduction, Scope of Action & Results

There are several thousand Park Homes spread across all regions of the UK, a significant number of which are providing permanent living accommodation to families and elderly individuals, many of who are in receipt of "qualifying benefits" and at risk from fuel poverty.

The construction specifications for the fabric of Park Homes, including those built to the latest BS 3632 2005 standard, provide for relatively poor levels of thermal insulation when compared to typical domestic dwellings and these low energy efficiency standards result in high space heating costs and CO2 emission levels.

It was believed that the addition of insulation to the external walls, roofs and under-floors of existing Park Homes would deliver a meaningful reduction in carbon emissions however there was no data base that would allow the carbon emission reduction, appropriate to each of the defined categories of Park Homes (i.e. by construction & heating fuel type), to be established

The Carbon Emissions Reduction Target (CERT) 2008 – 2011 scheme includes a 'Demonstration Action' for measures which *"are reasonably expected to achieve a reduction in carbon emissions, but for which a firm carbon emission reduction has not yet been evaluated"* and this project was undertaken by Scottish & Southern Energy plc. to develop solutions for improvement of the energy efficiency of Park Homes and to produce an accurate data set for the resultant CO2 reductions based on output from the TARBASE calculation model.

There are many options available on the UK market that can be adopted to achieve an effective improvement in the thermal insulation performance and energy efficiency of Park Homes, however in practical terms, lightweight wall panel systems and insulation measures for floors and roofs, that that can be applied externally within a relatively short time and with a minimum of disruption to occupiers, offer an advantage over alternatives involving internal works.

An initial step in the Demonstration Action was for a pilot project to be undertaken on a few Park Homes located on a site in Nottingham which trialled the installation of lightweight "Paraclad" insulated wall panels together with other insulation improvements to the under-floors and roofs.

The results from the Nottingham exercise proved positive and it was seen that there were a number of practical benefits in adopting the lightweight external panel system as an effective retrofit solution for Park Homes whilst recognizing that additional work was needed to improve the level of insulation across floors and roofs and to minimize unintentional air leakage across the envelope.

As part of this pilot exercise, TARBASE calculations were run to quantify CO2 emission levels and monitoring of both "pre and post–improvement" energy consumption and lifestyle influences was undertaken over a 12 month period.

Information relating to the Nottingham pilot is provided in **Appendix 1** of this report.

The data obtained from the Nottingham pilot assisted in the selection of a suitable refurbishment "mix" of insulation for the floors, walls and roofs taking into account the practicalities of installation, the resultant thermal insulation performance benefits and value for money.

Two types of external wall panel systems, "Blue Flag" and "Paraclad" were selected for the purposes of the Demonstration Action. These systems also included insulation improvement solutions for the under-floors and roofs of Park Homes.

Given the scale of the UK market, it was agreed with OFGEM that scientific performance appraisal data from a representative sample of 100 "TEST" Park Homes "as-existing" and of a minimum group of 10 homes "post refurbishment" (for each insulation system being assessed) would be required to allow full evaluation and accreditation of the base data for existing Park Homes and to confirm the level of CO2 savings that had been achieved by each insulation system via the action.

It was also agreed that the TARBASE calculation model would be used to quantify the level of carbon emission reduction achieved by the measures and to develop the categorisation matrix.

The next stage in the Demonstration Action process was for Alba Building Sciences Ltd to undertake a scientific thermal insulation performance assessment "pre-improvement" of an agreed representative sample of 100 existing Park Homes, sited at various locations across England, Wales and Scotland.

In addition to thermography, air change rate and dynamic in-situ U-value performance measurements, historical data on the fuel / energy consumption of these 100 homes together with details of energy usage and occupier lifestyle influences was used to inform the project.

The "pre-improvement" occupier questionnaires for these 100 homes can be found in **Appendix 7.**

The performance data relating to the 100 home "pre-improvement" assessments was input into the TARBASE calculation model in order to establish categories for the various types of Park Home and to determine the space heating and CO2 emission levels attributable to each.

The results of this 100 home "pre-improvement" assessment can be found in **Appendix 2 & 2A.**

When assessing the thermal insulation performance of the 100 test homes, a direct correlation was established between CO2 emission levels and the age of a Park Home, the air permeability of the envelope, and the relevant BS Standard 3632 to which it was constructed.

This allowed the various types of Park Homes to be split into categories based on the age and the relevant version of the BS3632 standard to which it was constructed.

The BS3632 standard was revised in 1981, 1989, 1995, and most recently in 2005 as per Table 2 below.

Table 2 : BS3632 Thermal Insulation Standards

BS 3632 Standard Published	**U Value** (W/m^2K) **Wall**	**U Value** (W/m^2K) **Floor**	**U Value** (W/m^2K) **Roof**
BS 3632 : **1970**	1.700	1.700	1.700
BS 3632 : **1981**	1.000	1.000	0.600
BS 3632 : **1989**	1.000	1.000	0.600
BS 3632 : **1995**	0.600	0.600	0.350
BS 3632 : **2005**	0.500	0.500	0.300

Those older Park Homes, for which base data is presented, were built to BS 3632:1970 and were poorest in terms of the "pre-improvement" thermal insulation performance of the envelope.

An improvement in the overall thermal insulation performance was established across those Park Homes built after the 1981 revision of the BS Standard and further incremental improvements in performance were measured during the "pre-improvement" assessments carried-out on those homes built to satisfy the subsequent 1995 and 2005 revisions to BS 3632.

Following categorisation and analysis of the "pre-improvement" assessment data of the 100 Park Homes, two groups of 10 homes were selected for installation of the insulation systems, on the basis that they provided a representative sample of the various categories of UK Park Home stock.

One group of 10 homes had the "Blue Flag" external insulation system with a site-applied polymer wet render coating installed across the walls together with "Solarguard" reflective-foil insulation fixed across the under-floors and blown - mineral fibre within 8 pitched roof voids. The remaining 2 homes had flat roofs where the existing mineral fibre insulation was retained.

The other group of 10 homes had the "Paraclad" external insulation panel system installed across the walls and "Icynene" water-based spray foam applied across the under-floors and within 5 pitched roof voids. Four (4) of the remaining homes had flat roofs where an overlay of PUR insulation with a single membrane covering was applied. The last home had a complex insulated roof which was retained.

On completion of the insulation improvements, the two groups of 10 homes were subjected to a "post-improvement" performance assessment by repeating the scientific techniques used for the "pre-improvement" measurements.

The data relating to the post-improvement assessments was then input into TARBASE in order to establish the carbon emission levels applicable across the various categories of Park Home contained within the two groups of 10.

The results of the 20 Home "post-improvement" assessments can be found in **Appendix 3A & 3B.**

Having established the "pre and post-improvement" performance of each of the 20 Homes it was then possible to compare these TARBASE results in order to quantify the level of space heating savings and carbon emission reductions that had been achieved by the action, appropriate to each of the defined categories and to attribute these savings to each of the insulation systems.

This follows the approach and method for typical house types and heating systems / fuels in CERT and details of the comparisons in performance levels are provided in **Appendix 4, 4A & 4B**.

The TARBASE comparisons show that a significant reduction in space heating and energy usage has been delivered "post-improvement" across all the 20 Park Homes and that Blue Flag and Paraclad insulation systems will deliver meaningful CO_2 savings, as tabulated in **Table 3** below**.**

A comparison was also run between standard SAP 2005 and TARBASE which shows that the resultant CO_2 predicted outputs are quite well matched although SAP is higher, and the details of this SAP via TARBASE comparison can be found in **Appendix 5**.

Table 3 : Reduction in Space Heating & Energy Usage

BS Standard	Reference		U-Value W/m²K Wall	Floor	Roof	ACH	KgCO2/m2	t/CO2/yr.	Space Heating Reduction % kWh/ m2
BS 3632: 1970	BS 3632: 1970		1.700	1.700	1.700	-	-	-	-
	Alba Measured 100 (Average)		1.890	1.405	1.083	0.82	97.70	3.27	-
	Blue Flag	Pre	1.272	0.919	0.680	0.65	69.70	4.43	-
	Blue Flag	Post	0.317	0.320	0.433	0.45	50.80	3.12	53 %
	Paraclad	Pre	1.332	0.793	1.121	0.74	70.25	2.60	-
	Paraclad	Post	0.293	0.290	0.306	0.44	53.31	2.10	78 %
BS 3632: 1981 & BS 3632: 1989	BS 3632: 1981 / 1989		1.000	1.000	0.600	-	-	-	-
	Alba Measured 100 (Average)		1.406	1.079	1.005	0.70	89.40	3.218	-
	Blue Flag	Pre	0.817	0.623	0.560	0.63	70.47	3.18	-
	Blue Flag	Post	0.302	0.338	0.413	0.41	55.87	2.52	45 %
	Paraclad	Pre	0.797	0.605	0.970	0.74	59.51	2.90	-
	Paraclad	Post	0.296	0.222	0.435	0.40	47.68	2.35	65 %
BS 3632: 1995	BS 3632: 1995		0.600	0.600	0.400	-	-	-	-
	Alba Measured 100 (Average)		0.900	0.768	0.690	0.58	70.00	3.144	-
	Blue Flag	Pre	0.624	0.421	0.437	0.56	43.40	2.60	-
	Blue Flag	Post	0.204	0.350	0.291	0.31	31.48	2.06	47 %
	Paraclad	Pre	0.629	0.495	0.450	0.44	47.04	3.28	-
	Paraclad	Post	0.229	0.206	0.196	0.25	37.39	2.60	70%
BS 3632: 2005	BS 3632: 2005		0.500	0.500	0.350	-	-	-	-
	Alba Measured 100 (Average)		0.680	0.384	0.635	0.31	65.28	3.00	
	Blue Flag	Pre	0.680	0.384	0.635	0.31	65.28	3.00	
	Blue Flag	Post	0.238	0.268	0.540	0.25	54.57	2.37	39%
	Paraclad	Pre	0.680	0.384	0.635	0.31	65.28	3.00	
	Paraclad	Post	0.272	0.177	0.292	0.18	50.20	2.18	44%

From Table 3, an analysis of the Tarbase savings applicable across the various categories of Park Home, has shown that the Blue Flag system delivered an average reduction in space heating of 46% which equate to annual savings in CO2 emission levels of between 0.54 to 1.31 tonnes and lifetime saving (30 years) of between 16.2 and 39.3 tonnes CO2.

A similar Tarbase analysis shows that the Paraclad system delivered an average reduction in space heating of 64% which equate to annual savings in CO2 emission levels of between 0.55 to 0.96 tonnes and lifetime saving (30 years) of between 16.5 and 28.8 tonnes CO2.

In addition to the calculated Tarbase savings that were projected for each insulation system, monitoring of the internal living space temperatures, occupier lifestyle influences, actual fuel usage, electricity consumption and costs was undertaken across the 20 homes over the winter periods November 2009 to May 2010 (pre) and 2010/2011 (post).

The "pre-improvement" monitoring proved that many homes were not being heated to a reasonable internal comfort level with a daytime average temperature of 19ºC for the heated living spaces.

The "post-improvement" monitoring data produced a higher daytime average comfort temperature of 22.5ºC for the heated living spaces providing evidence of "occupier take-back" which has an impact on the level of actual cost and energy savings delivered by the action.

Post-Improvement Temperature Monitoring Data is provided in **Appendix 8A & 8B**.

The audit of actual costs "post-improvement" confirmed that significant savings were being realised across the group of 10 homes insulated with the Blue Flag system. A reduction in fuel usage was accompanied by reduced expenditure on space heating and on electric energy consumption i.e.:-

Blue Flag AP 31 - 40	**Average Savings (Pre v Post Improvement)**	
	£ Cost Saving as %	**Consumption Saving as %**
Heating / Fuel	35 %	39 %
Electricity	12 %	11 %
An average combined Heat & Power £ cost saving of 31 %		

The audit of actual costs "post-improvement" confirmed that significant savings were being realised across the group of 10 homes insulated with the Paraclad system. A reduction in fuel usage was accompanied by reduced expenditure on space heating and on electric energy consumption i.e.:-

Paraclad AP 41 - 50	**Average Savings (Pre v Post Improvement)**	
	£ Cost Saving as %	**Consumption Saving as %**
Heating / Fuel	53 %	54 %
Electricity	11 %	12 %
An average combined Heat & Power £ cost saving of 44 %		

A full analysis of the cost savings applicable to each system / home is presented **in Appendix 6.**

Project Methodology

The aim of this demonstration action is to determine the level of carbon emission savings that can be attributed to insulation systems used for the refurbishment of Park Homes, following CERT methodology, from data obtained both “pre-improvement” and “post-improvement”.

An initial step in the Demonstration Action was for a pilot project to be undertaken on a few Park Homes located on a site in Nottingham which trialled the installation of lightweight “Paraclad” insulated wall panels together with other insulation improvements to the under-floors and roofs.

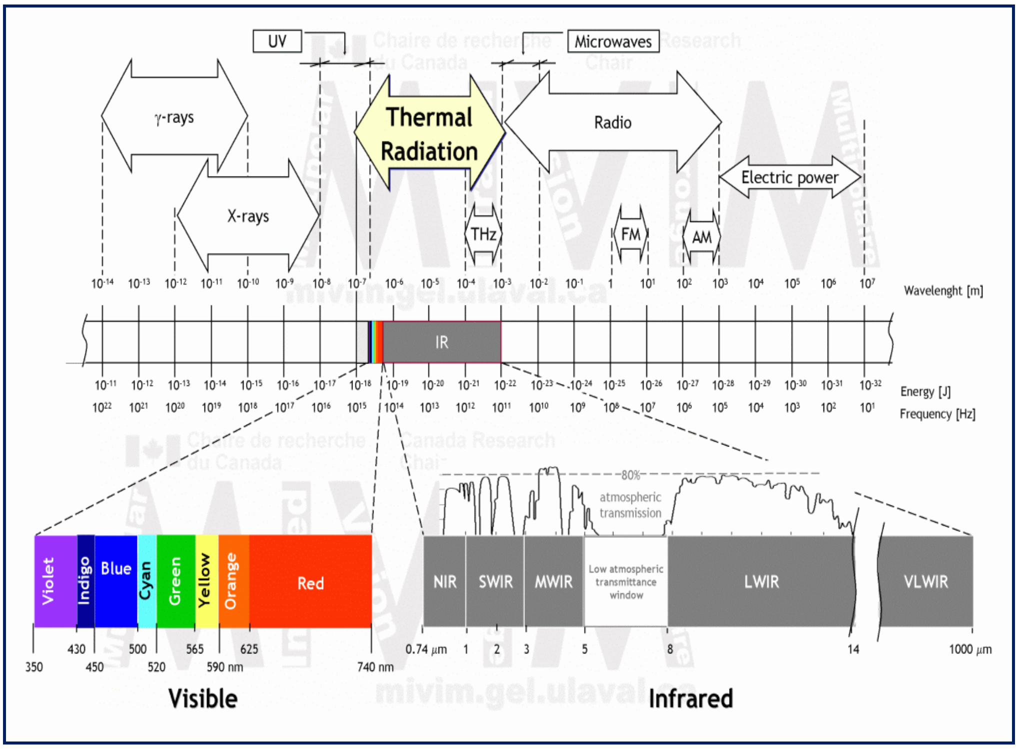
The Pilot Project and its findings are detailed later in this report **(see Page 18)**

As part of this pilot (and subsequently to evaluate both the “pre” and “post-improvements” involved in the main UK-wide project) Alba Building Sciences Ltd carried-out a series of scientific thermal insulation performance assessments which included the use of Infrared Thermography, In-Situ U-Value Measurements and Tracer Gas Decay Testing, all as detailed below.

Infrared Thermography

Infrared (meaning far red) is the name given the part of the electromagnetic spectrum that occurs just beyond the red end of the visible light spectrum (see Figure 1).

Figure 1 : Infrared Spectrum



All matter that is warmer than absolute zero (-273°C) emits infrared radiation and the temperature of the emitting body generally governs the level of emission. The warmer the body is, the greater the quantity of infrared energy given off and temperature also governs the wavelength of the infrared energy emitted.

An infrared camera is a device that can detect the various levels of infrared radiation being emitted across the surface of an object and which can produce a visual “thermographic” image made up of the range of temperature differentials, captured across that surface, at that moment in time.

For the thermographic assessments, Alba Building Sciences employed a FLIR SC660 Long Wave Infrared Camera and an Inframetric's 760E Broad-Band Thermal Imaging System.

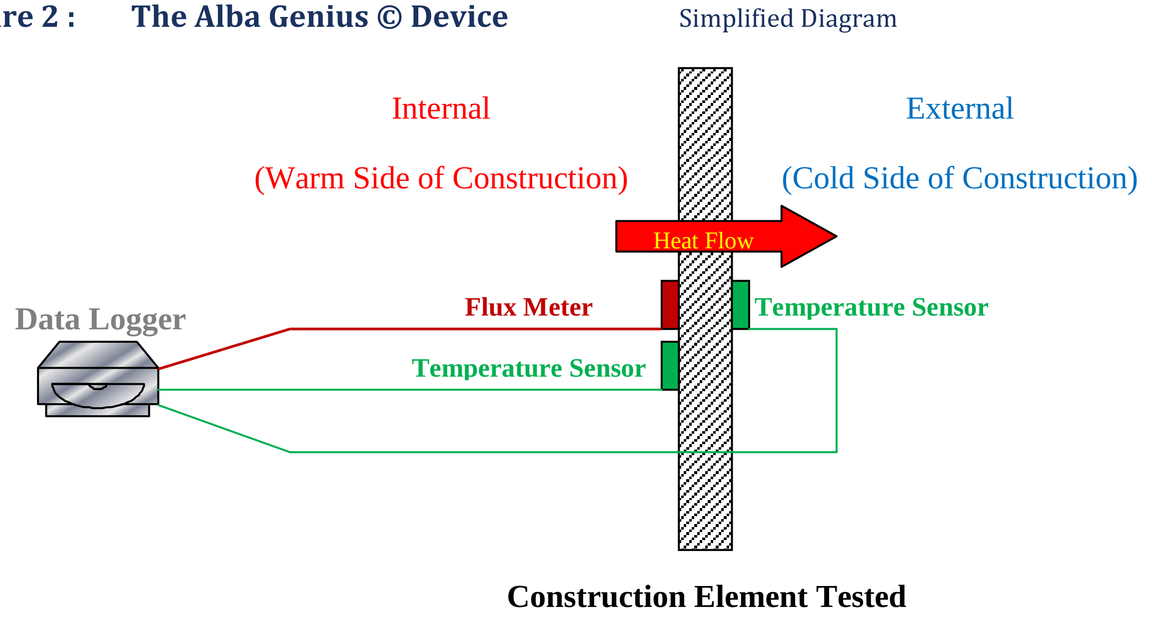
Comprehensive infrared thermal imaging surveys were undertaken in order to assess the "as-built" thermal insulation performance of the external envelope of the Park Homes and to identify the location and extent of any thermal anomalies where energy / heat loss was occurring.

Weaknesses such as missing or misplaced thermal insulation, design & build quality defects, thermal bridging, unintentional warm air leakage or cold air infiltration pathways generate a thermal anomaly in the infrared. These types of weaknesses can have a significant impact upon the "as-built" air tightness and thermal insulation performance levels achieved by the external envelope of any dwelling, and their effect can be particularly significant on a lightweight construction such as a Park Home.

In-Situ U-Value Measurement (Thermal Transfer)

In order to further quantify the "as-built" thermal insulation performance of the wall, roof and floor construction elements of park homes, The thermal transfer coefficient was measured in-situ by employing the **Alba Genius©** U-Value measurement device (See Figure 2 below) installed in accordance with ISO 9869:1994: *Thermal Insulation - Building elements - In-situ measurement of thermal resistance and thermal transmittance.*

Figure 2 : The Alba Genius © Device



The **Alba Genius©** device accurately quantifies heat flows through the construction and includes data input from a number of temperature and flux sensors which is processed to produce an in-situ performing U-Value for that part of the construction, averaged over the period of the measurement.

The **Alba Genius©** device is placed in-situ for a number of days in order to record and process the range of data that requires to be taken into account given the dynamic nature of non-steady-state measurements and the effect these variations have on building fabric performance.

Locations selected for measurement across the walls, roof and floors of Park Homes, are based on infrared data to ensure they are representative of the thermal insulation performance of the construction.

Tracer Gas Decay Testing

Tracer gas decay tests provide a measure of how the air-flows within a building alter under normal operating conditions and can therefore be used to quantify the air-change and air- infiltration / leakage rates of the dwelling in a "passive" state,

Alba undertakes Tracer Gas testing by way of the concentration decay method using CO2 and the methodology adheres to the relevant standard ISO 12569:2000. *Thermal performance of buildings - Determination of air change in buildings - Tracer gas dilution method.*

To determine the average air change rate via the concentration decay test method, a volume of tracer gas (CO2) is introduced into the test zone and once a uniform concentration is reached, the level is recorded at intervals and its subsequent decay charted.

The resultant data provides the passive Air Change Rate (ACH) per hour which informed input into the TARBASE calculation model.

Tarbase Calculation Model

The Tarbase Domestic Model was developed by Heriot Watt University to assess the energy performance of dwellings and options for carbon-saving refurbishments. While subject to the usual limits of steady-state building models, Tarbase allows the estimation to be tailored to a specific dwelling, with improved sensitivity to accommodate lifestyle variables.

A description of the **TARBASE DOMESTIC MODEL** is provided later in this report **(see Page 15)**

With regard to the demonstration action, all TARBASE calculations were based on "as-built" input from the "in-situ" scientific performance assessments and were run to quantify the CO2 emission levels both "pre and post–improvement" on the Nottingham Pilot Study and on the UK-wide project.

A comparison was also run between standard SAP 2005 and TARBASE. **(See Appendix 5)**

Monitoring & Occupier Questionnaire : "Pre & "Post Improvement"

In addition to the output from the Tarbase calculation model, monitoring of actual fuel and energy costs was undertaken both "pre and post–improvement" over the winter period 2009/10 and 2010/11.

The **MONITORING** of actual energy and cost savings are detailed later in this report **(see Page 48)**

When comparing pre and post-improvement heating costs, fuel and energy consumption it was necessary to take into account occupier lifestyle and a detailed questionnaire was completed for every one of the Park Homes that was subject to assessment within the demonstration action.

For the "pre" and "post"-improvement **OCCUPIER QUESTIONNAIRE** see **Appendix 7 & 7A**.

On average the "post-improvement" temperature within the main living space of each park home was 3.5ºC higher than that "pre-improvement" as the occupiers enjoyed a certain amount of "take-back"

It was also evident that the ability of the park homes to attain and retain these internal comfort levels was significantly better "post-improvement" due to the reduction in air leakage and insulation overall.

Tarbase Domestic Model

As part of the Tarbase project, the Tarbase Domestic Model was developed to assess the energy performance of dwellings and options for carbon-saving refurbishments. While subject to the usual limits of steady-state building models, the Tarbase model allows the estimation to be tailored to a specific dwelling, with climate and internal activity accounted for.

The use of such models can be a valuable, and convenient, way of quantifying the approximate performance of a range of individual dwellings, leading the user to solutions for carbon-saving improvements.

Allowing the model to capture the variation in building specification is of great importance, as is the philosophy of seeing the building as being a product of location, construction and activity/operation.

Introduction

The Tarbase project is part of the Carbon Vision Building Programme, and was a four-year study to investigate carbon-saving refurbishments suitable for UK domestic and non-domestic buildings.

As part of this investigation, the use of building modeling and simulation to estimate energy performance of buildings was examined.

For domestic buildings, the project concluded that there was a role to play for steady-state models, providing appropriate models were used with suitable input. Additionally the limits of such models should be understood prior to commencing with the modelling, where issues such as overheating, detailed energy load profiles and effects occurring at a more detailed temporal resolution cannot be appropriately investigated with steady-state tools.

Rather than use existing steady-state models, where restrictions often exist for the type of input used, a new model, the Tarbase Domestic Model, was formulated to estimate energy performance metrics for individual dwellings with a view to understanding the energy-saving potential of domestic refurbishments to existing buildings.

This model is a combination of accepted theory, design guides and bespoke models created by the Tarbase project.

Use of steady-state modelling

Steady-state modelling can be used to compare relatively simple dwellings, with defined operation and occupancy, for studies looking to gauge the efficiency and condition of one property against another, or the wider building stock.

This information can be used for decisions relating to energy-saving refurbishments, for example the level of insulation required or likely effect of onsite power generation.

While absolute energy and carbon metrics are provided by such steady-state models, perhaps of more importance is the relative difference between performance metrics of different dwellings.

This difference can guide an engineer or architect towards building-specific actions rather than approaching a dwelling as merely a building represented by average stock information.

As with any model, caution should still be advised when choosing the inputs used in a steady-state model so that buildings are accurately represented. However, with 26 million dwellings in the UK, there is a need for an efficient tool that is suitable for comparing these homes against each other.

One approach to this problem would be to encourage a high degree of standardisation of input for all modeling exercises which might mean linking building element U-value to property age, general assumptions of glazing area (both of which can be the case with the Reduced Data Standard Assessment Procedure (rdSAP)) or using just one climate/location for all space heating calculations (for the full version of the Standard Assessment Procedure (SAP).

Standardisation in the current tools for dwellings can also be seen in the approach to internal activity and occupancy. All versions of SAP, including the latest 2009 version, have had various relationships that a user of a model should apply when estimating the number of occupants in that dwelling (which is given as a function of total floor area).

While this has a certain justification for new buildings (which are yet to be occupied), it does mean that an existing dwelling will be assessed for a theoretical occupancy, not the actual occupancy.

This level of standardisation encourages the user of, in particular, SAP-type models to treat a dwelling like a stock-average dwelling, and so ignores the deviation of a specific dwelling from the average.

The danger of this assumption is that, even allowing for errors implicit to steady-state modelling, the modeller is not accurately describing the dwelling being investigated. The advice emanating from that tool, while relevant to the modelled building, might be less relevant for the actual building.

Choosing the correct input, and allowing a model to be flexible enough to account for variability in this input, is therefore fundamental to achieving useful output from steady-state modeling.

Tarbase Domestic Model

The Tarbase Domestic Model uses a combination of bespoke algorithms and design guidance to estimate the total energy consumption of a dwelling, split into the various energy categories described below.

The model can also provide the user with refurbishment options for carbon-saving targets, including various onsite generation technologies.

The model has been used across a range of dwellings within the Tarbase project with the aim of producing automated output such as Figure A.

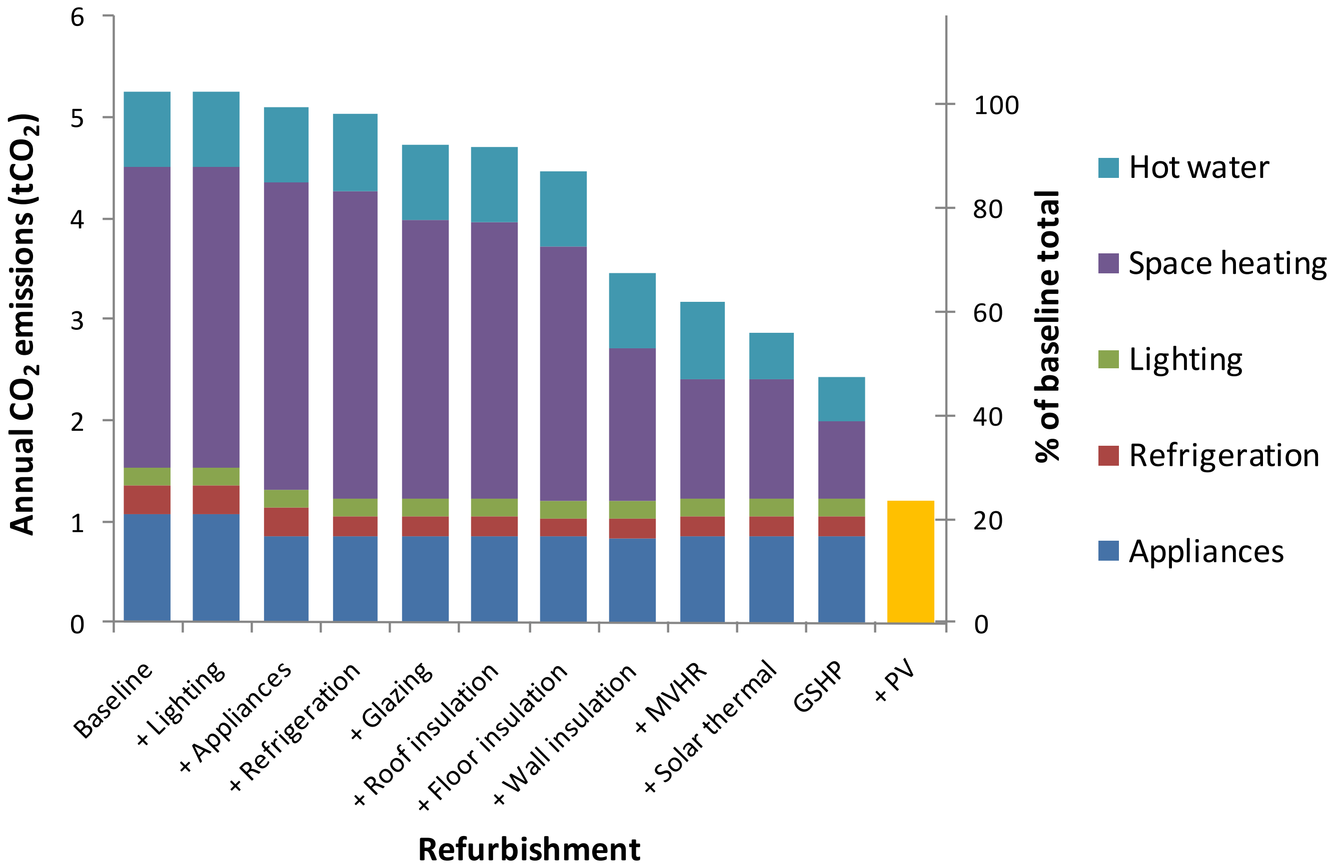
In Figure A the effect of each refurbishment measure is shown as applied cumulatively to a baseline building.

Other forms of tailored outputs can be generated which demonstrate the relative effects of building heat loss, appliance energy use, hot water usage etc. on the overall building carbon emissions.

This information can then be used to decide what aspects of the building should be improved first to reach the goal of an energy-efficient building.

The methodology used to calculate the carbon emissions and energy consumption of the inputted dwelling is summarised below, split into the various energy categories.

Figure 3 : Example output of the Tarbase Domestic Model for chosen refurbishments applied cumulatively



Pilot Project

An initial step in the Demonstration Action was for a pilot project to be undertaken on a few Park Homes located on a site in Nottingham which trialled the installation of lightweight "Paraclad" insulated wall panels together with other insulation improvements to the under-floors and roofs.

Detailed information relating to the Nottingham pilot is provided in **Appendix 1** of this report.

As part of this pilot exercise, Alba Building Sciences Ltd carried out a Pre and "post improvement" scientific thermal insulation performance assessment comprised of Infrared Thermography, In-Situ U-Value Measurements and Tracer Gas Decay Testing.

In addition to the scientific performance assessment, TARBASE calculations were run to quantify CO2 emission levels and monitoring of both "pre and post–improvement" energy consumption and lifestyle influences was undertaken over a 12 month period. (**See Table 4 below**)

Table 4 : Pilot Project Pre v's "post improvement" Results Summary

Alba Ref	"Pre improvement" Performance Results							"Post improvement" Performance Results					
	U-Value W/m²K			ACH	tCo2/yr	KgCo2/m2		U-Value W/m²K			ACH	tCo2/yr	KgCo2/m2
	Walls	Roof	Floor					Walls	Roof	Floor			
GMST 6	1.019	0.737	0.923	0.22	3.1	80.6		0.367	0.737	0.403	0.16	2.5	66.1
GMST 13	0.985	0.679	0.895	0.28	2.9	73.0		0.327	0.344	0.386	0.15	2.5	62.2
GMST 37	1.162	0.994	0.917	0.26	2.7	81.4		0.386	0.428	0.412	0.19	2.0	59.0
GMST 42	1.04	0.915	0.844	0.19	2.9	63.1		0.422	0.915	0.392	0.12	2.4	52.1

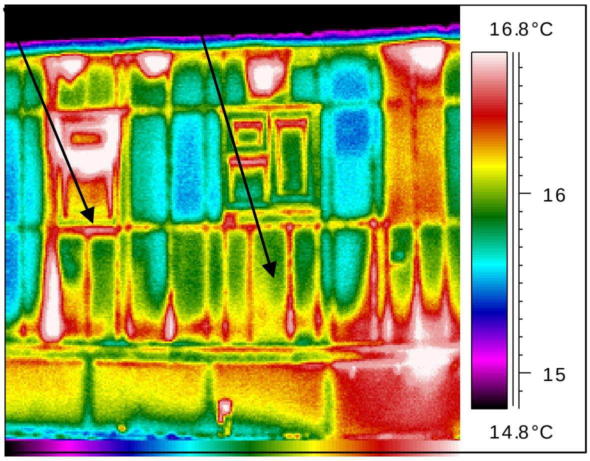
The data obtained from the Nottingham pilot assisted in the selection of a suitable refurbishment "mix" of insulation for the floors, walls and roofs taking into account the practicalities of installation, the resultant thermal insulation performance benefits and value for money.

The results from the Nottingham exercise proved positive and it was evident that there were a number of practical benefits in adopting the lightweight external panel system as an effective retrofit solution for Park Homes whilst recognizing that additional work was needed to improve the level of insulation across floors and roofs and to minimize unintentional air leakage across the envelope.

Examples of the infrared thermographic assessments undertaken at the "pre and post-improvement" stage of this pilot project are provided in the following section of this report.

GMST 37

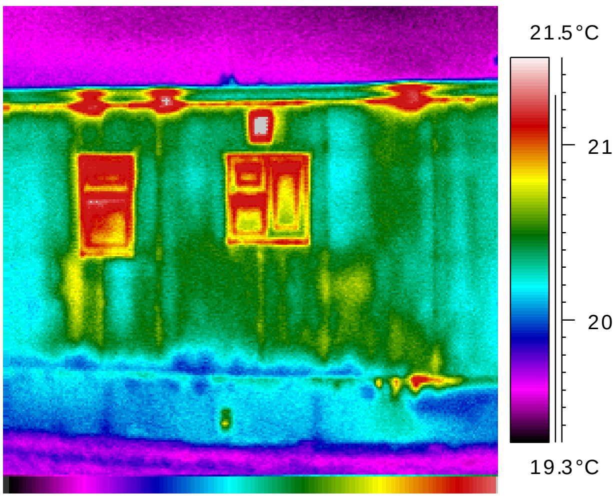
"Pre-Improvement" Inspection



In the thermal image "pre-improvement", it is clear that significant heat loss is occurring across the building envelope and that this can be attributed to thermal bridging across the timber frame construction in addition to warm air leakage at critical junction details.

The thermographic inspection also identified a number of anomalies that were indicative of significant heat loss, occurring across the floor construction.

"Post-Improvement" Inspection

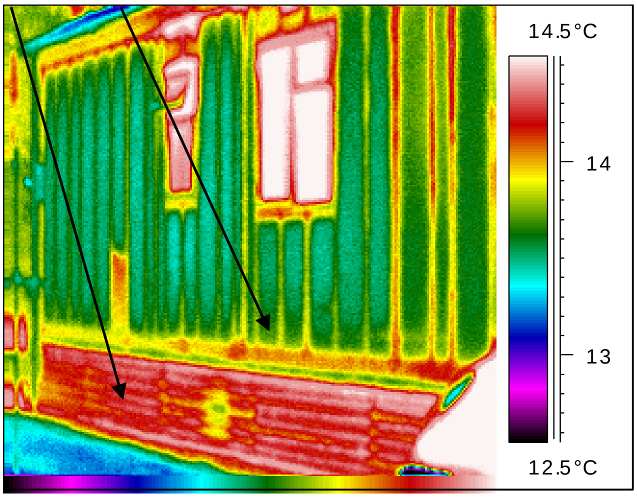


It can be seen in the above thermal image "post-improvement" that the number of heat-loss pathways across the building envelope have been significantly reduced (i.e. when compared to the "pre-improvement" image)

Whilst the number of anomalies had been reduced it was evident that further performance improvements could be achieved by reducing unintentional air leakage at critical junction details.

GMST 6

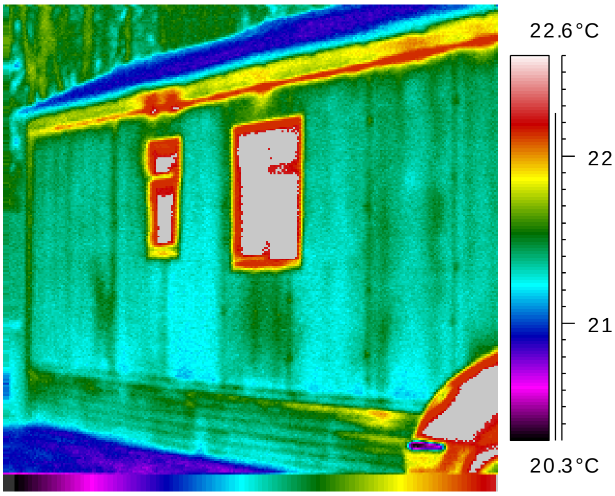
"Pre-Improvement" Inspection



In the thermal image "pre-improvement", it is clear that significant heat loss is occurring across the building envelope and that this can be attributed to thermal bridging across the timber frame construction in addition to warm air leakage at critical junction details.

The thermographic inspection also identified a number of anomalies that were indicative of significant heat loss, occurring across the floor construction.

"Post-Improvement Inspection"



It can be seen in the above thermal image "post-improvement" that the number of heat-loss pathways across the building envelope have been significantly reduced (i.e. when compared to the "pre-improvement" image)

Whilst the number of anomalies had been reduced it was evident that further performance improvements could be achieved by reducing unintentional air leakage at critical junction details.

"Pre-Improvement" Performance Assessment

The second stage in the Demonstration Action process was to undertake a scientific thermal insulation performance assessment of existing UK Park Homes stock.

Given the scale of the UK market, it was agreed with OFGEM that performance appraisal results would be required from a representative sample of 100 "TEST" Park Homes, sited at various locations across England, Wales and Scotland in order to establish a credible data set for the "as-built" condition.

In addition to the scientific thermal insulation performance assessment, which involved thermography, air change rate and dynamic in-situ U-value performance measurements, historical data on the energy consumption of these 100 homes together with details of energy usage and occupier lifestyle influences was collated and used to inform the project.

The performance data relating to the 100 home "pre-improvement" assessments was then input into the TARBASE calculation model in order to establish categories for the various types of Park Home and to determine the space heating and CO2 emission levels attributable to each.

The results of this 100 home "pre-improvement" assessment can be found in **Appendix 2 & 2A.**

When assessing the thermal insulation performance of the 100 test homes, a direct correlation was established between CO2 emission levels and the age of a Park Home, the air permeability of the envelope, and the relevant BS Standard 3632 to which it was constructed.

This allowed the various types of Park Homes to be split into categories based on the age and BS3632 standard to which it was manufactured.

The BS3632 standard was revised in 1981, 1989, 1995, and most recently in 2005 as shown in **Table 5**.

Table 5 : BS3632 Thermal Insulation Standards

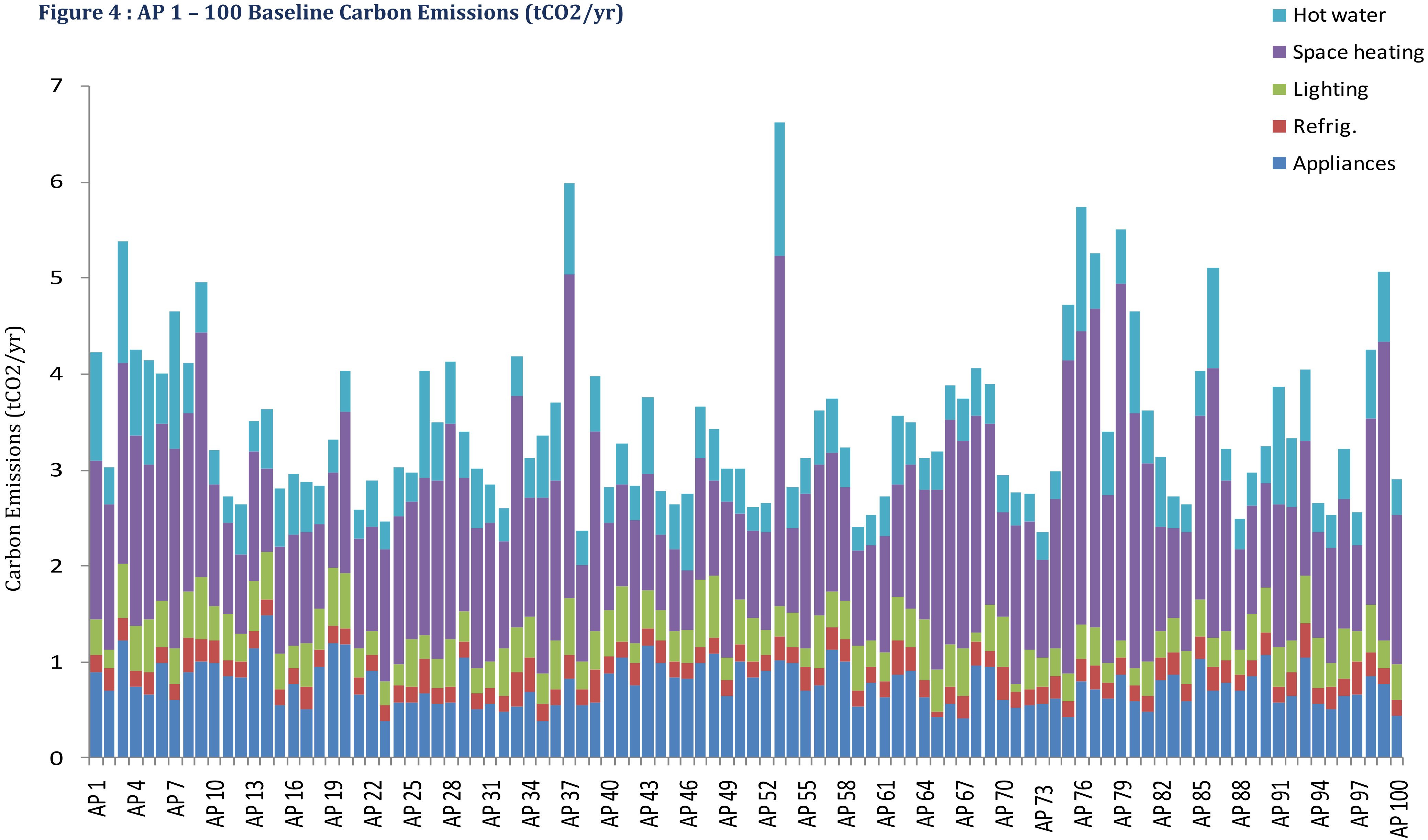
BS 3632 Standard Published	**U Value** (W/m^2K) **Wall**	**U Value** (W/m^2K) **Floor**	**U Value** (W/m^2K) **Roof**
BS 3632 : **1970**	1.700	1.700	1.700
BS 3632 : **1981**	1.000	1.000	0.600
BS 3632 : **1989**	1.000	1.000	0.600
BS 3632 : **1995**	0.600	0.600	0.350
BS 3632 : **2005**	0.500	0.500	0.300

Those older homes, for which baseline data is presented, were built to BS 3632:1970 and were poorest in terms of the pre-improvement thermal insulation performance of the envelope and CO2 Score

An improvement in the overall thermal insulation performance was established across those Park Homes built after the 1981 revision of the BS Standard and further incremental improvements in performance were measured during the "pre-improvement" assessments carried-out on those homes built to satisfy the subsequent 1995 and 2005 revisions to BS 3632.

Baseline data on carbon emissions "pre-improvement" is presented in **Figure 4** on the following page.

Figure 4 : AP 1 – 100 Baseline Carbon Emissions (tCO2/yr)



AP 1 – 100 – "Pre-Improvement" Thermographic Findings

A Comprehensive external infrared thermal imaging survey of 100 park homes (AP1 to AP100) was undertaken in order to assess the "as-built" thermal insulation performance of the external envelope and to identify the location and extent of any thermal anomalies relating to energy / heat loss.

See Appendix 2A for AP 1 to AP 100 "Pre-Improvement" Thermographic Data.

A number of thermal anomalies were identified across the envelopes of all of the 100 homes surveyed and many of the defects and weaknesses found were common across the various types and age groups.

These anomalies were indicative of a number of thermal insulation weaknesses all as described below as explained below and examples of which are presented in the following thermographic images.

- **Thermal Bridging**: The type of construction used in Park Homes includes a support framework (usually timber) to which is attached the internal / external walls, floors and roof. This frame is un-insulated and where it is in direct contact with the external walls a (cold) thermal bridge is created.

- **Air Leakage / Heat Loss Pathways:** The method of construction used for Park Homes means that a number of unintentional warm air leakage (cold air infiltration) pathways are often created at "critical junction details", particularly at the floor to wall, window to wall and wall to roof junctions.

- **Floor Construction:** The basic design of park homes means that they are raised off the ground and when positioned on a site, they have a support wall constructed around the perimeter, creating an enclosed space below the floor. Many homes have ineffective insulation on the underside of the raised floor which allows thermal bridging and cold air infiltration to occur, all of which has a negative impact on the heat retention within the internal living spaces.

- **Wall Construction:** The method of construction combined with minimal insulation and cold air infiltration across and behind the external walls of park homes, does result in significant heat loss occurring directly through the fabric. This effect is clearly seen in the external infrared images and is exaggerated at locations where central heating radiators are installed (often below window units). The effect of heat loss due to small unintentional leakage pathways at electrical sockets is also apparent.

- **Roofs:** The design of residential park homes usually involves either a pitched tiled roof or one which is slightly curved (almost flat). The type of insulation found within the roof void varies according to the design and age of the home however this insulation is often ineffective as the method of construction leads to unintentional warm air leakage and / or cold air infiltration.

- **Windows:** The thermographic survey identified areas of increased heat-loss at projected window details (due to un-insulated cills). A number of homes also had single-glazed window units which are obviously poorer in terms of thermal insulation properties when compared to double-glazed units.

Thermal Bridging

The type of construction used in Park Homes includes a support framework for attaching the internal / external walls, floors and roof.

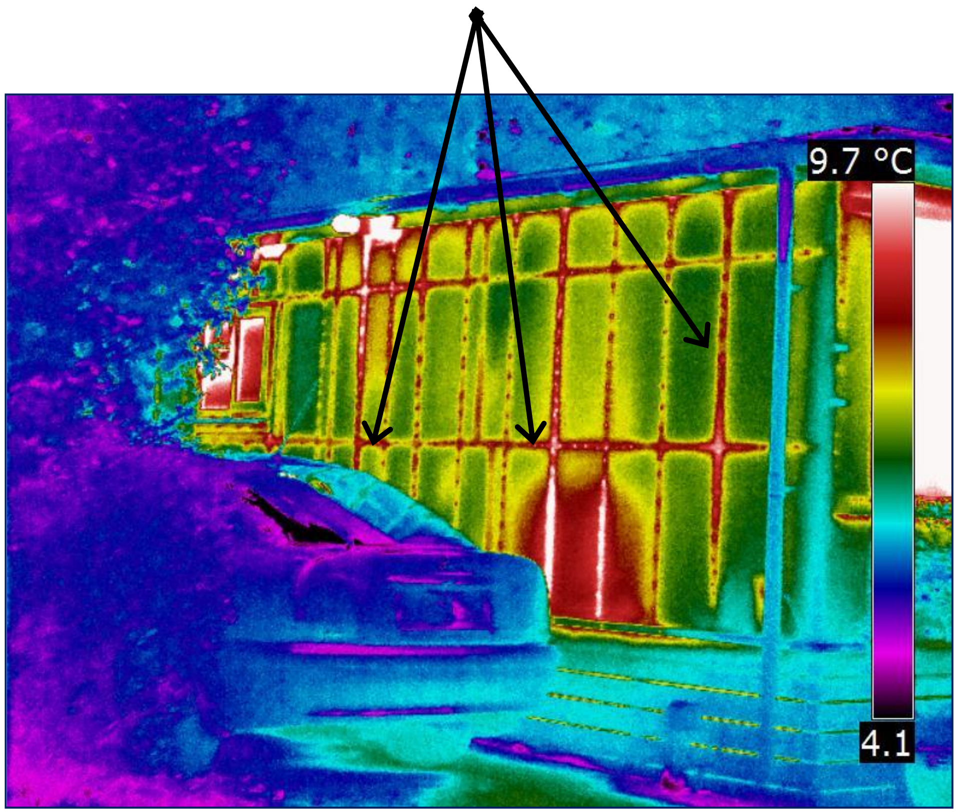
This frame is un-insulated and where it is in direct contact with external walls it creates a thermal bridge that penetrates the fabric.

Defects Identified

1. Thermal Bridging is highlighted across the frame construction.

   It can be identified at both horizontal and vertical members (seen as red lines) in the thermal image.

1



1

Thermal Bridging

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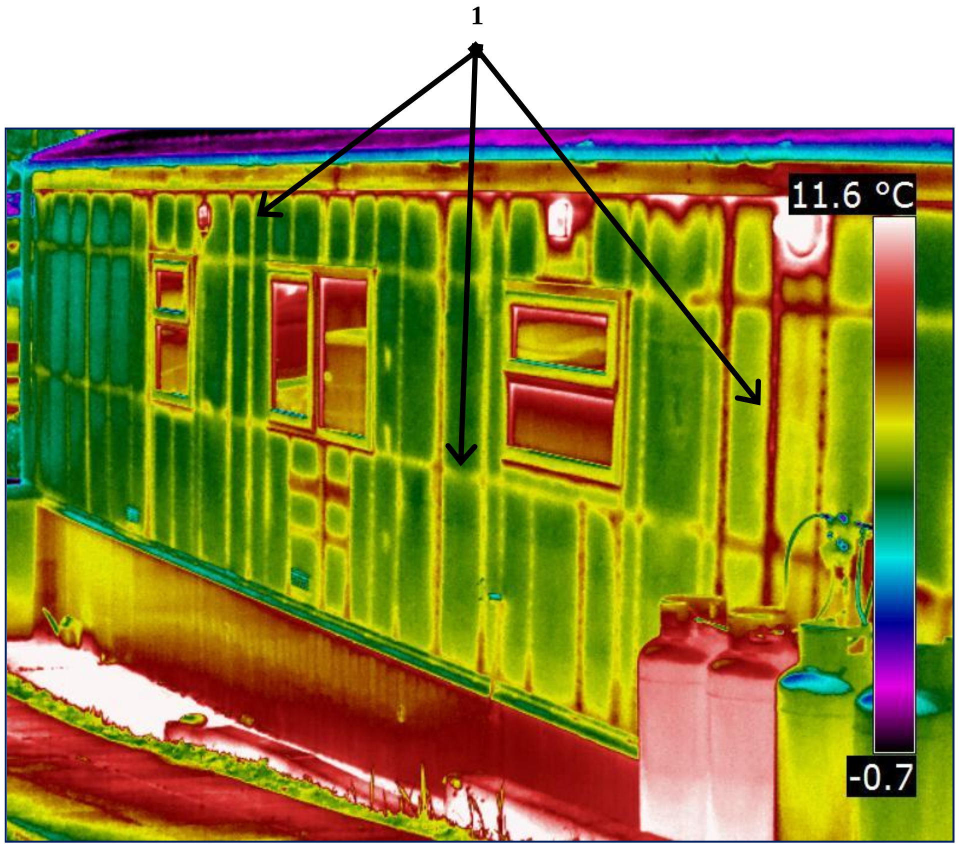
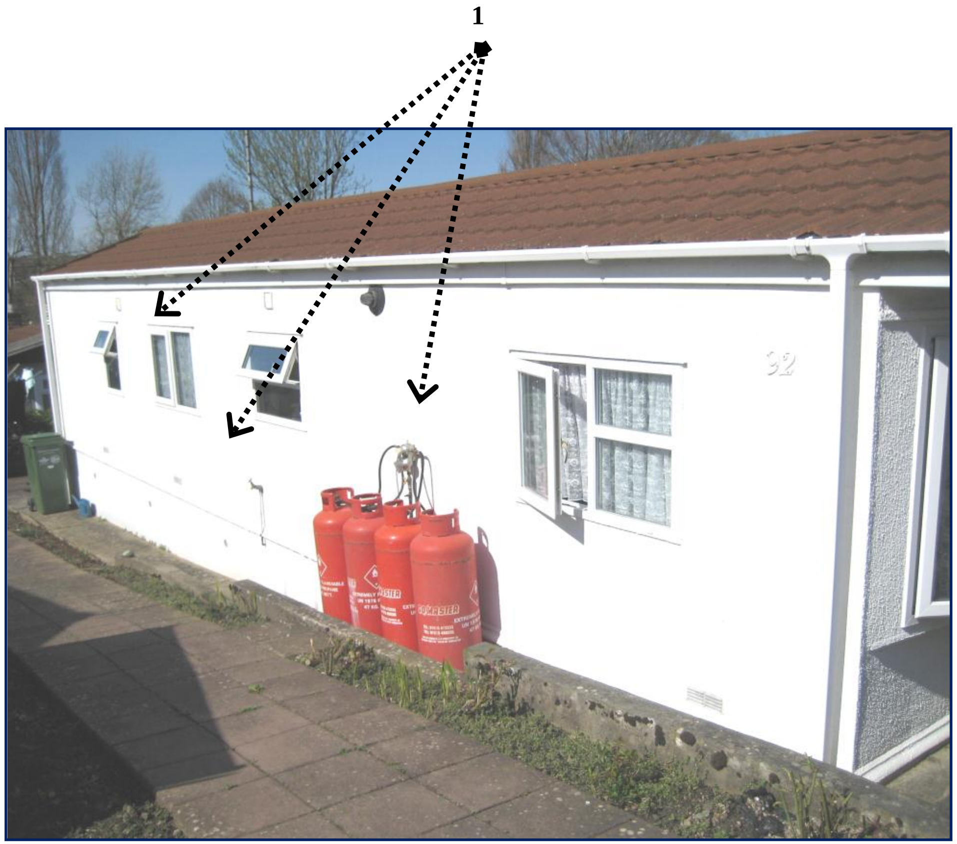
This frame is un-insulated and where it is in direct contact with external walls it creates a thermal bridge that penetrates the fabric.

Defects Identified

1. Thermal Bridging is occurring across the frame construction.

   It can clearly be identified at horizontal and vertical members (seen as red and yellow lines) in the thermal image.





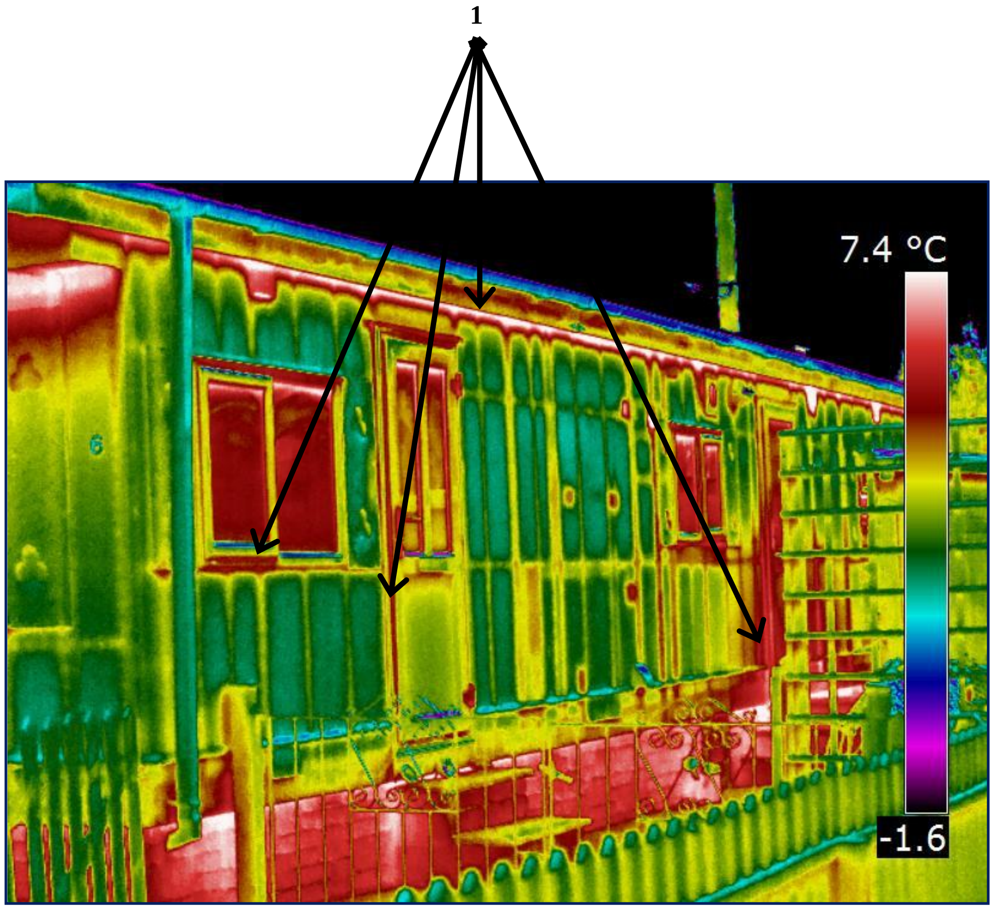
Air Leakage / Heat Loss Pathways

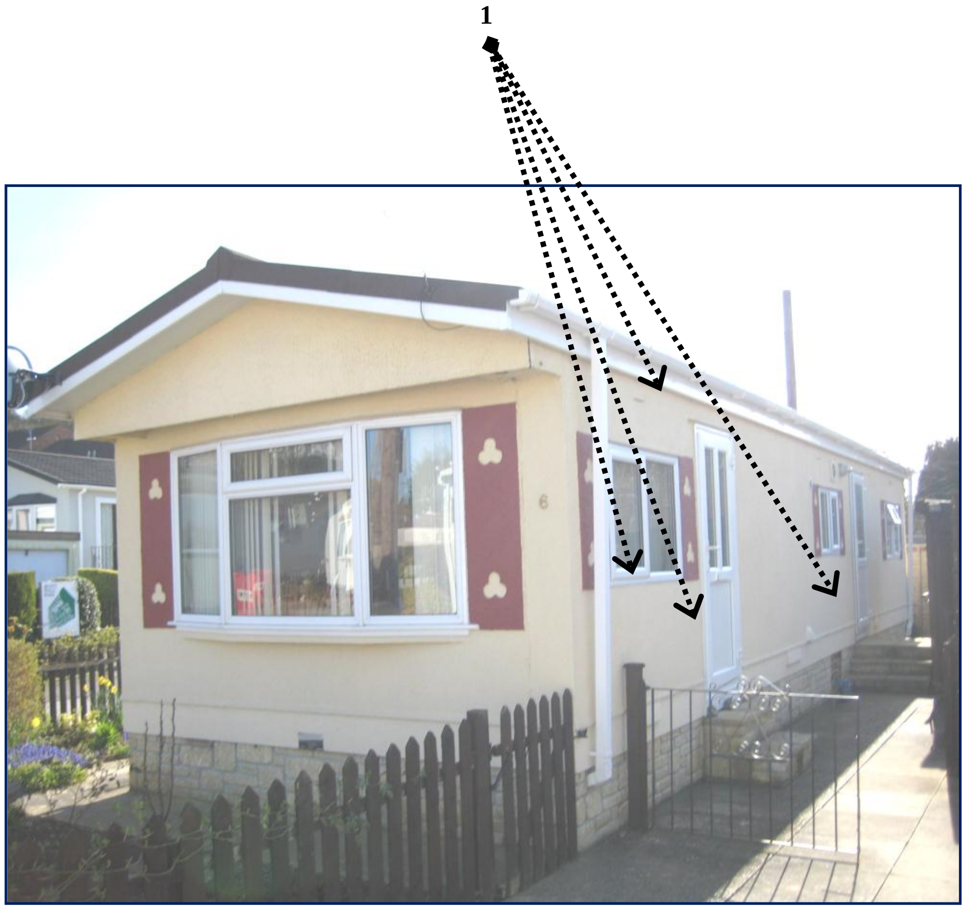
The method of construction used for Park Homes means that a number of unintentional warm air leakage pathways often exist at "critical junction details", particularly at the entrance doorway, floor to wall, window to wall or and wall to roof junctions.

Defects Identified

1. Typical Air Leakage Pathways in a Park Home (Critical Junctions)

Window to Wall | Door to Wall | Wall to Roof | Floor to Wall





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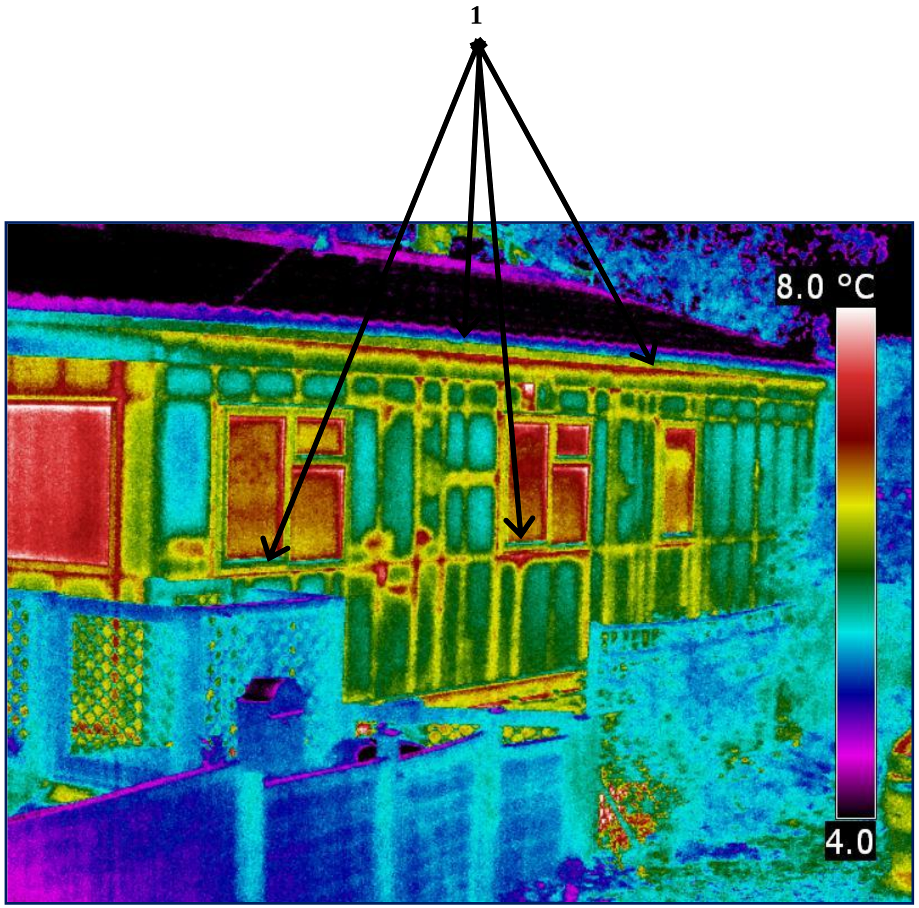
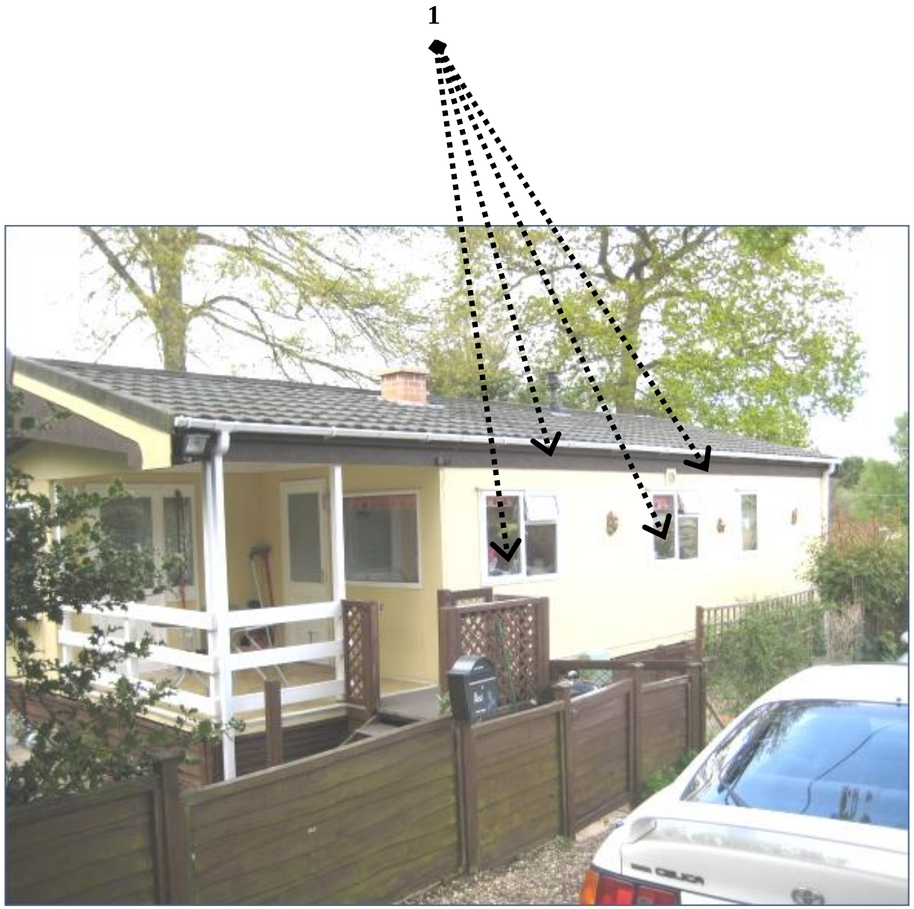




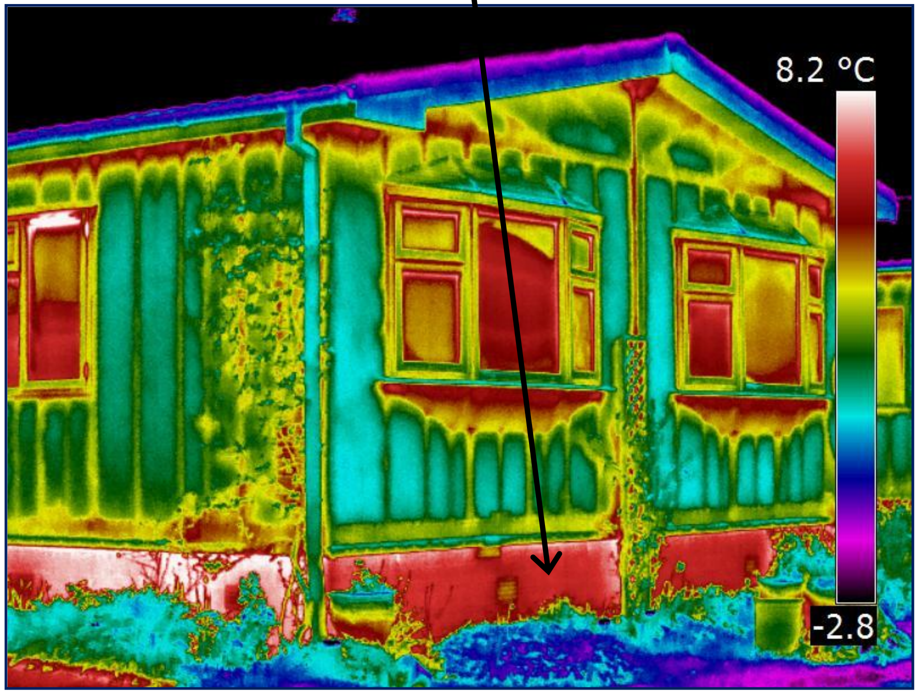
Floor Construction

The design of Park Homes means that, when positioned on-site, they are raised off the ground and are usually supported by a wall which creates an enclosed space below the floor, around the perimeter. Many homes have ineffective insulation on the underside of the raised floor which allows unintentional cold air infiltration / warm air leakage to occur. A thermal bridge is also often identified running along the park home frame / support wall junction all of which has a negative impact on the heat retention within the internal living spaces of the home.

Defects Identified

1. Heat Loss at floor construction.

1



1

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Defects Identified

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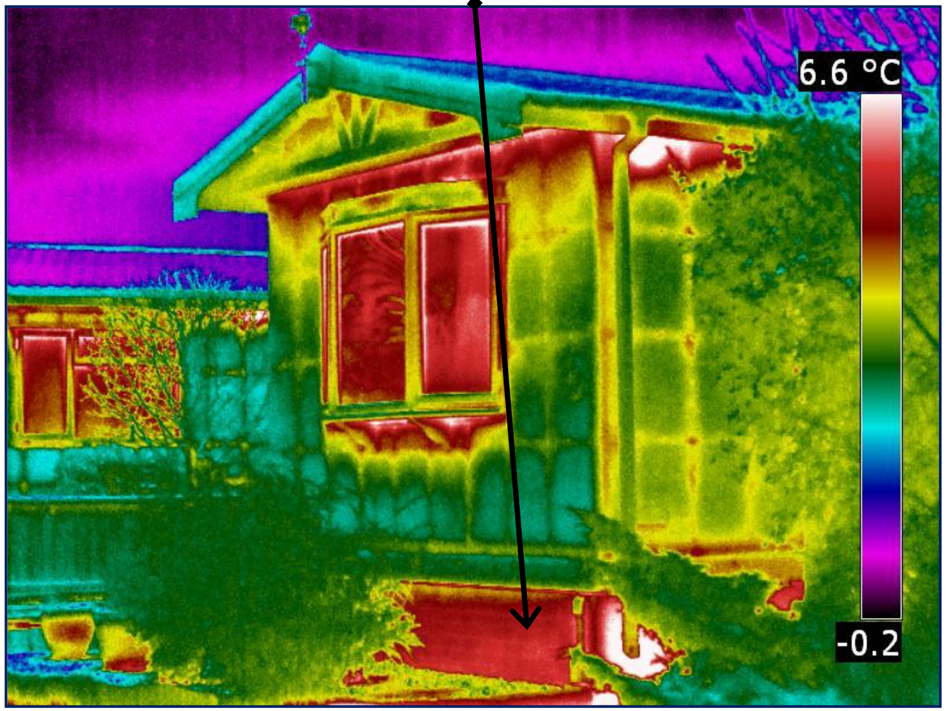
1



1

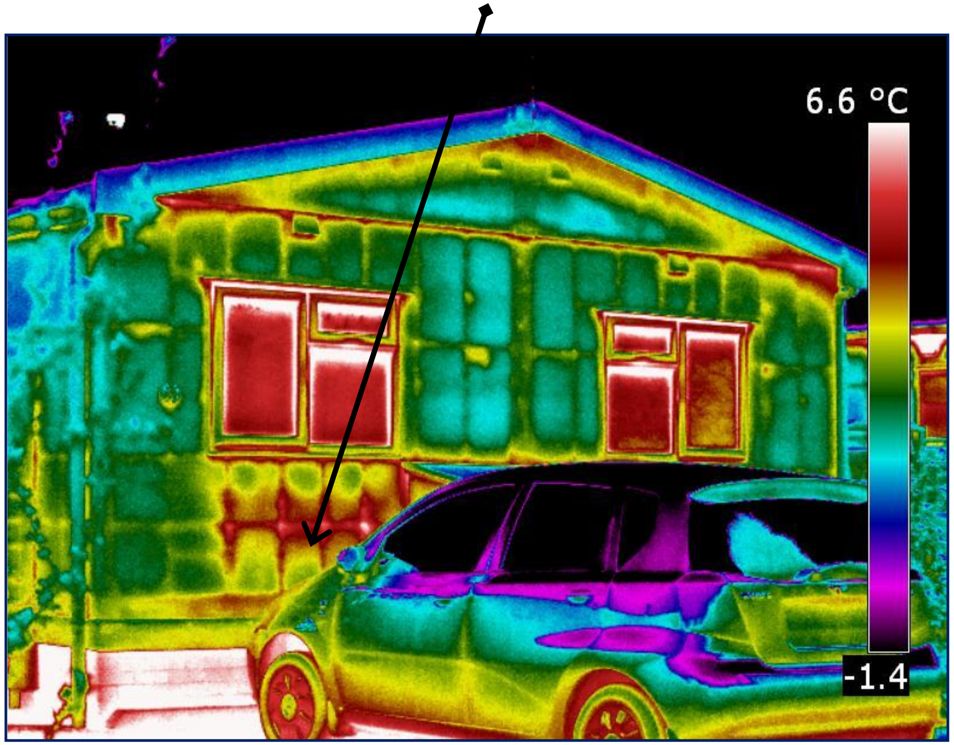
Wall Construction

The method of construction combined with minimal insulation and cold air infiltration across the walls of park homes does result in areas where significant heat loss is occurring directly through the fabric. This effect is clearly seen in the infrared and is exaggerated at locations where central heating radiators are installed (often below window units). The effect of heat loss via small unintentional leakage pathways at electrical sockets is also apparent.

Defects Identified

1. Direct Heat Loss through building fabric adjacent to an internal radiator.

1



1

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Defects Identified

1. Direct Heat Loss through building fabric adjacent to internal radiator.

1

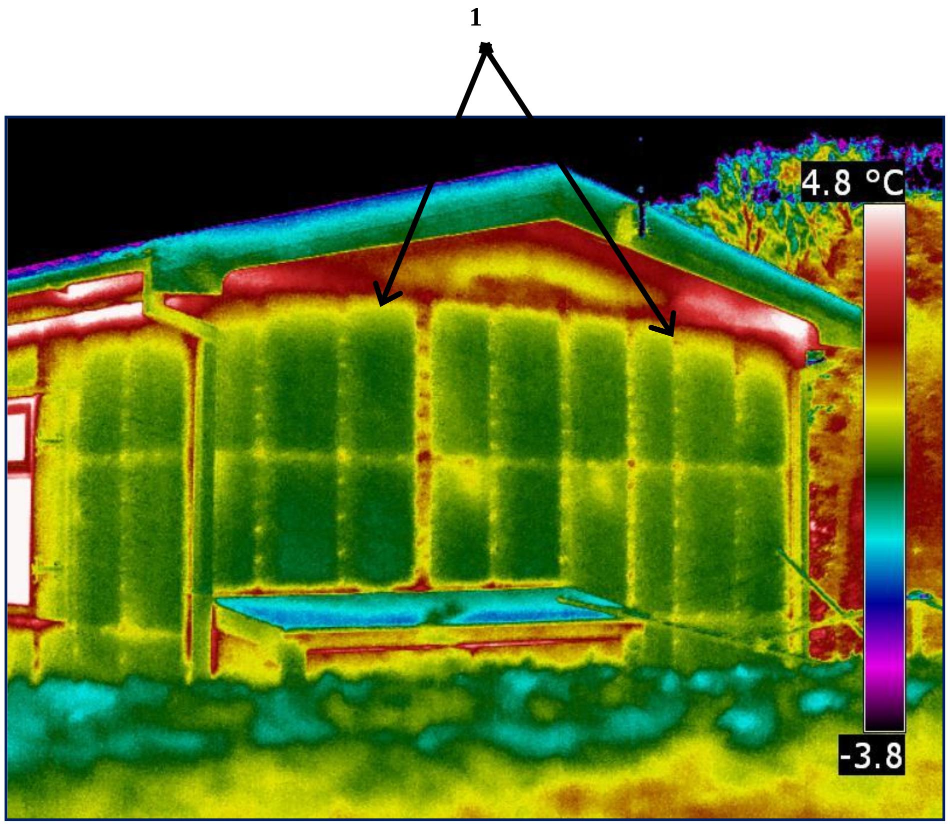
1

Roofs

The design of residential park homes usually involves either a Pitched tiled roof or one which is slightly curved (almost flat). The type of insulation found within the roof void varies according to the design and age of the home however the insulation is often ineffective as the method of construction leads to unintentional warm air leakage or cold air infiltration.

Defects Identified

1. Heat loss at roof detail.



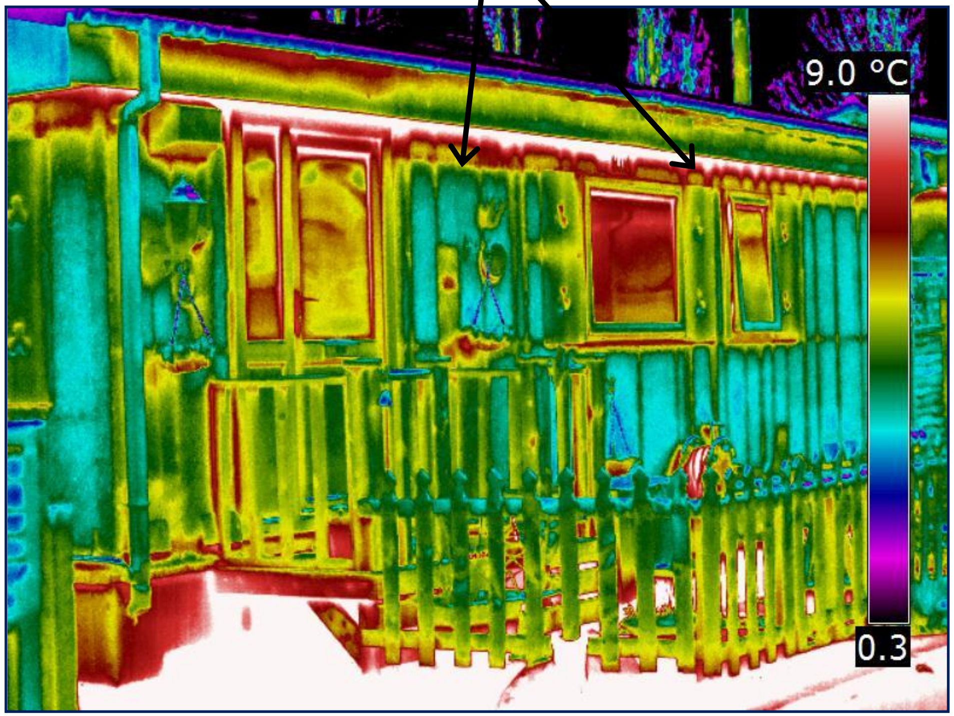
Roofs

The design of residential park homes usually involves either a Pitched tiled roof or one which is slightly curved (almost flat). The type of insulation found within the roof void varies according to the design and age of the home however the insulation is often ineffective as the method of construction leads to unintentional warm air leakage or cold air infiltration.

Defects Identified

1. Heat loss at eaves detail / wall to roof junction.

1



1

Windows

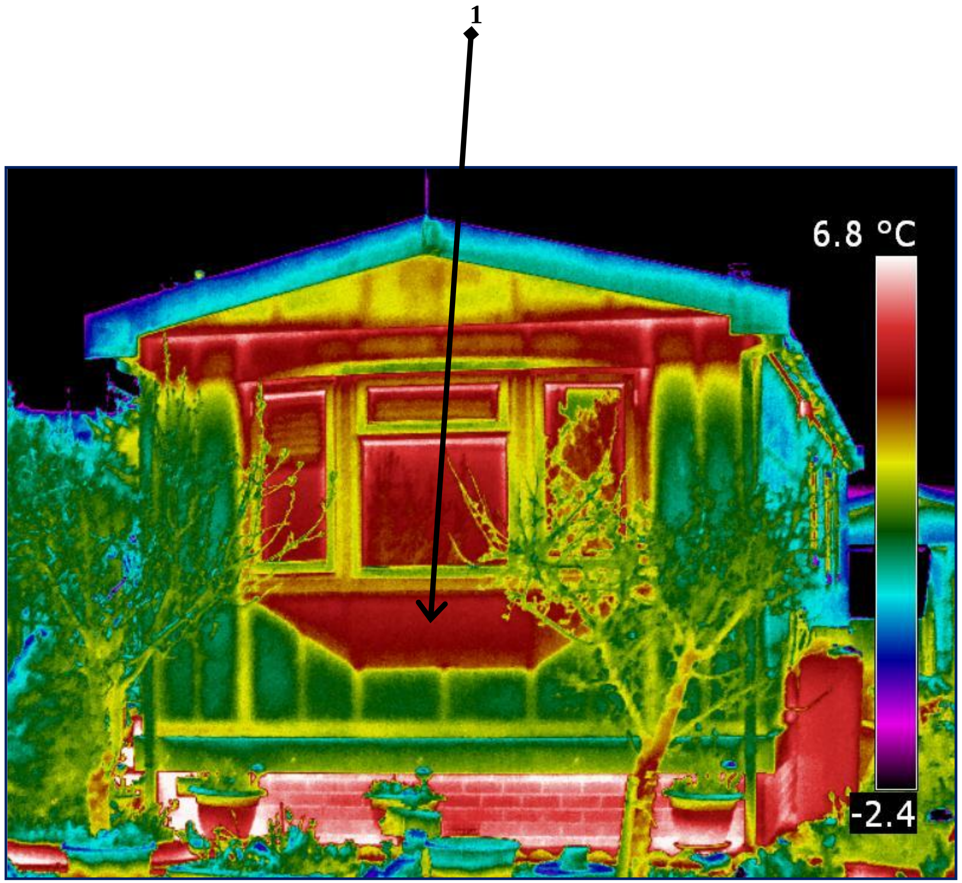
Increased heat loss is evident at the underside of projected windows

This is due to an un-insulated cill detail which is allowing direct conduction heat loss from the internal living space.

Defects Identified

1. Direct heat loss at projected window detail.

This park home has a "box out" detail under the window.



Windows

Increased heat loss is evident at the underside of the projected window details.

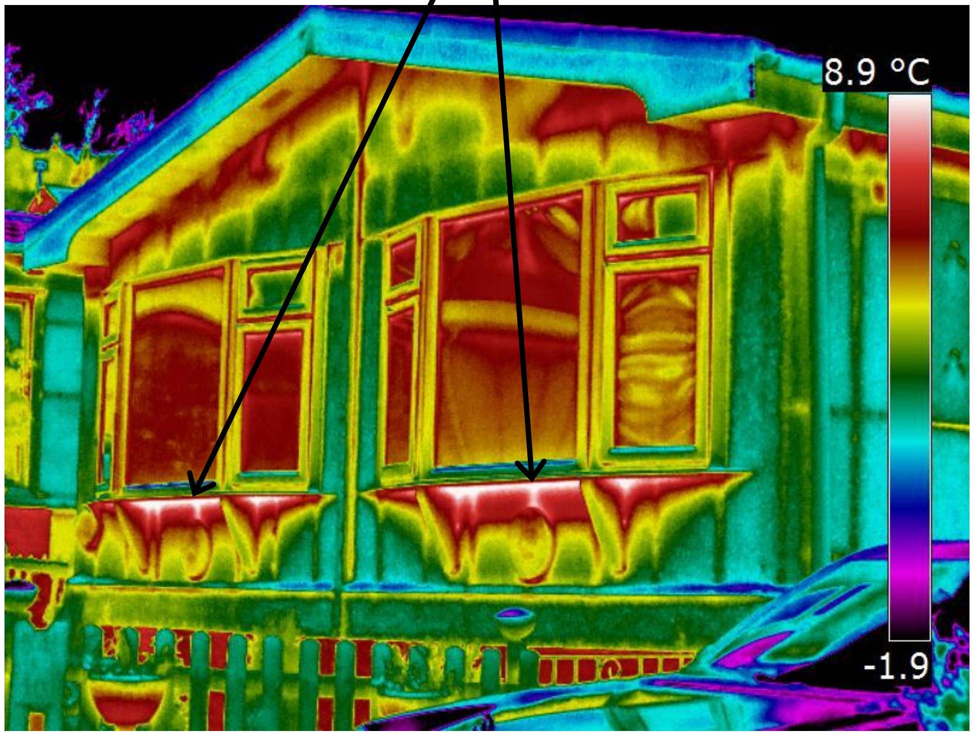
This is due to un-insulated cill details, allowing direct warm air leakage from the internal living spaces.

Defects Identified

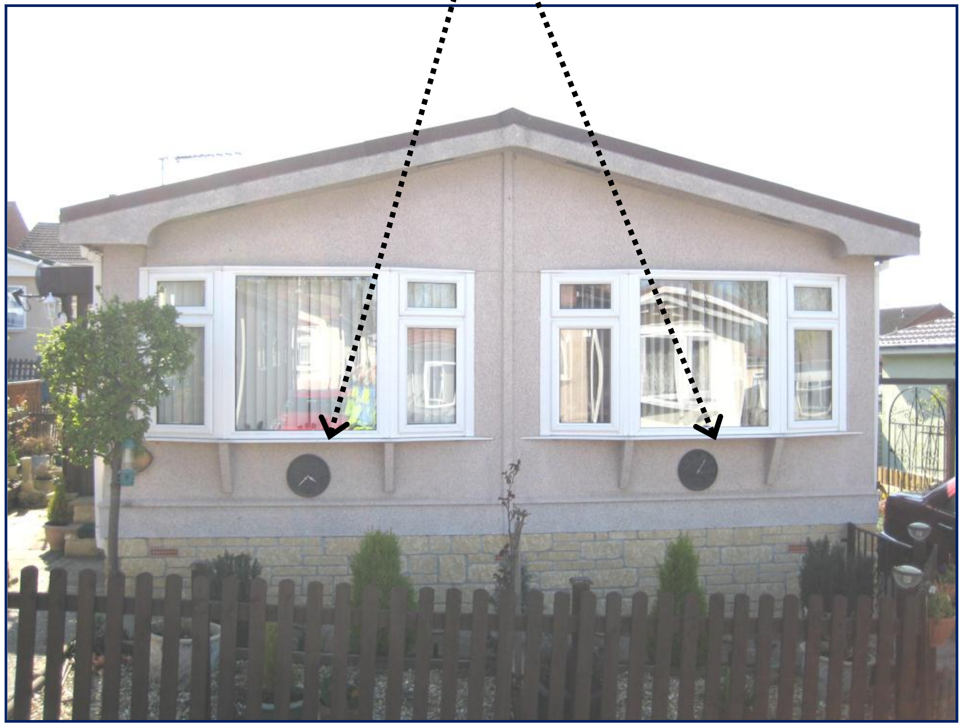
1. Direct heat loss at projected window detail.

This park home has no “box out” detail under the window.

1



1



"Post-Improvement" Assessment

To allow full evaluation and accreditation of the base data for existing Park Homes and to confirm the level of CO2 savings that had been achieved by each insulation system via the action, it was agreed with OFGEM that, following analysis of the "pre-improvement" assessment data of the 100 Park Homes, two groups of 10 homes would be selected for installation of insulation improvements, on the basis that each group provided a representative sample of the various categories of UK Park Home stock.

One group of 10 homes had the "Blue Flag" external insulation system applied.

This system comprised of an insulated EPS (Plustherm)board being fixed to all external walls before application of a polymer wet-render coating to provide weather protection.

A reflective-foil insulation (Solarguard) was fixed and sealed across the under-floors and blown mineral fibre insulation was installed within 8 of the homes with pitched roof voids.

The remaining 2 park homes within the "Blue Flag" group had flat roofs with existing insulation and a honeycomb type construction which prevented further intervention.

The other group of 10 homes had the "Paraclad" MK11 external insulation panel system comprising PIR insulation board with a factory applied ParaTex acrylic high-build finish installed across the walls and water-based spray foam (Icynene) applied across all of the under-floors and within 5 of the homes that had pitched roof voids.

Within the "Paraclad" group, 4 of the remaining homes had flat roofs where an overlay of PUR insulation boards protected by a single membrane covering was applied.

The remaining home had an insulated flat roof with a honeycomb type construction which prevented further intervention.

Following on from completion of the insulation improvements, the two groups of ten homes were subjected to a "post-improvement" performance assessment by repeating the scientific techniques used for the "pre-improvement" measurements.

The performance data relating to these "post-improvement" assessments was then input into TARBASE in order to establish the carbon emission levels applicable across the various categories of Park Home contained within the two groups of 10.

The results of the 20 Home "post-improvement" assessments can be found in **Appendix 3A & 3B.**

The **"Blue Flag"** results are summarised in **Table 6 and Figure 5** on **page 37**.

The **"Paraclad"** results are summarised in **Table 7 and Figure 6** on **page 38.**

Table 6 : "Post improvement" Assessment Data for Blue Flag

AP Code	U Value (W/m^2K)			Infiltration Rate AC/H	CO2 Emissions tCO2/yr.
	Wall	Roof	Floor		
AP 31	0.35	0.96	0.45	0.52	2.28
AP 32	0.20	0.29	0.35	0.31	2.06
AP 33	0.33	0.76	0.25	0.56	3.17
AP 34	0.32	0.30	0.33	0.42	2.47
AP 35	0.31	0.51	0.36	0.47	2.72
AP 36	0.29	0.21	0.32	0.36	2.85
AP 37	0.30	0.23	0.39	0.38	3.72
AP 38	0.26	0.31	0.33	0.29	1.88
AP 39	0.37	0.28	0.34	0.41	3.03
AP 40	0.23	0.21	0.22	0.39	2.34

Figure 5 : Carbon Emissions "Post Improvement" for Blue Flag

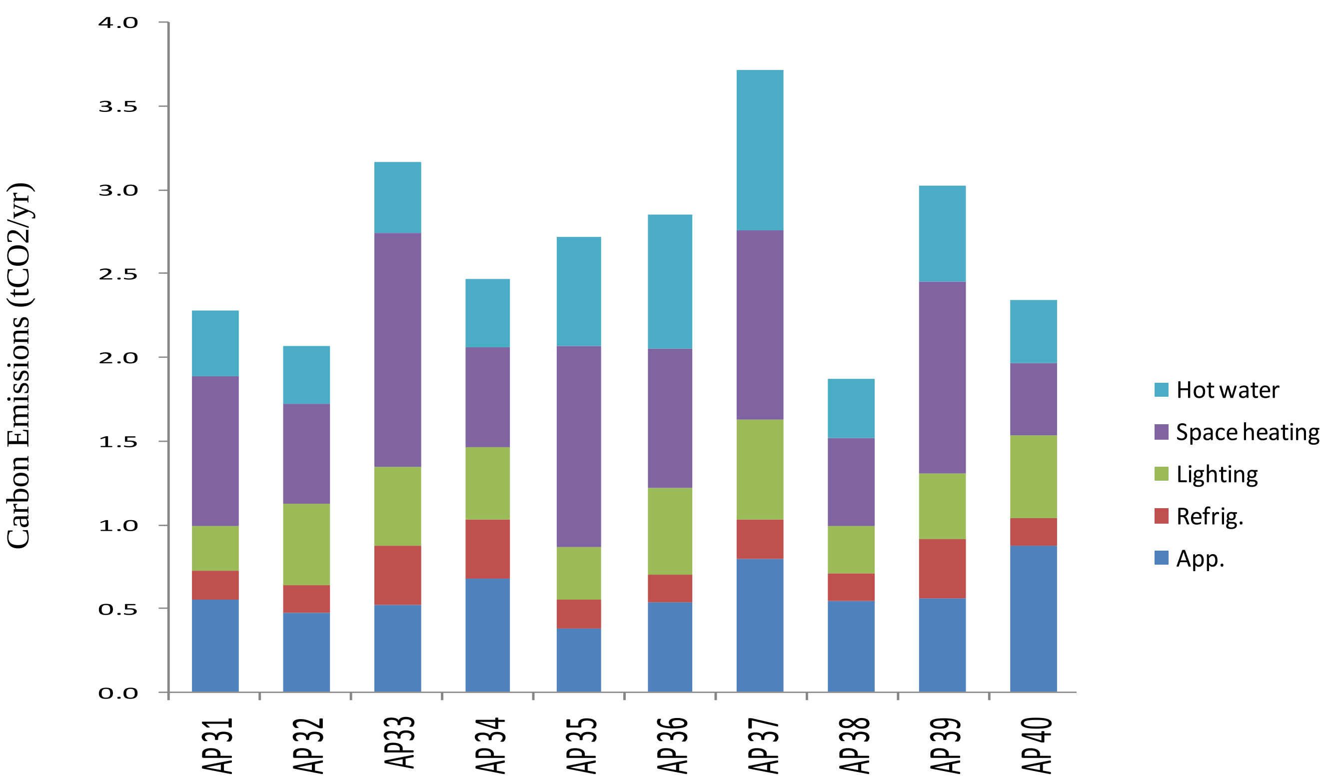
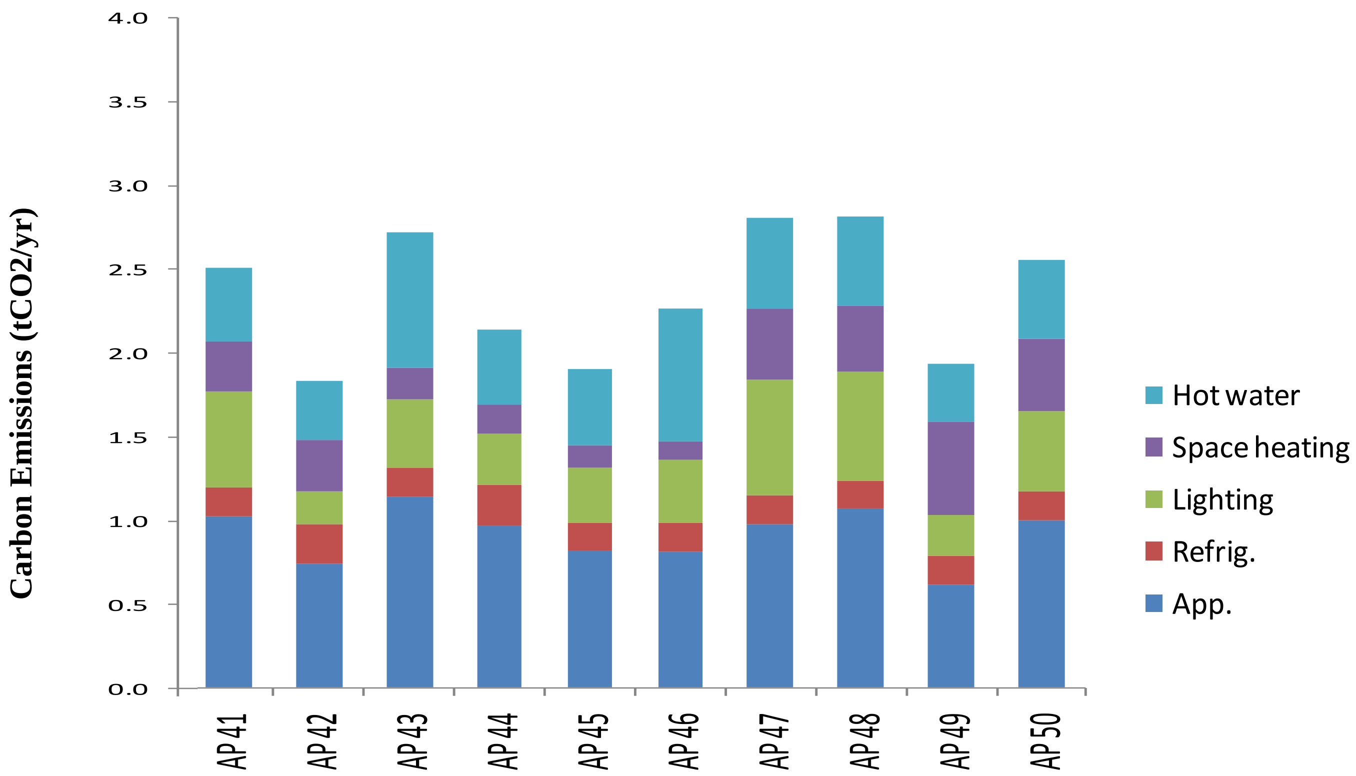


Table 7 : "Post Improvement" Assessment Data for Paraclad

AP Code	U Value (W/m²K)			Infiltration Rate AC/H	CO2 Emissions tCO2/yr.
	Wall	Roof	Floor		
AP 41	0.29	0.20	0.25	0.26	2.51
AP 42	0.35	0.34	0.24	0.54	1.83
AP 43	0.26	0.28	0.21	0.29	2.72
AP 44	0.33	0.36	0.23	0.36	2.14
AP 45	0.24	0.25	0.32	0.44	1.90
AP 46	0.26	0.24	0.25	0.29	2.26
AP 47	0.19	0.16	0.15	0.22	2.80
AP 48	0.17	0.18	0.18	0.23	2.82
AP 49	0.33	0.35	0.40	0.47	1.94
AP 50	0.26	0.51	0.21	0.44	2.56

Figure 6 : Carbon Emissions "Post Improvement" for Paraclad



Comparison "Pre v Post-Improvement"

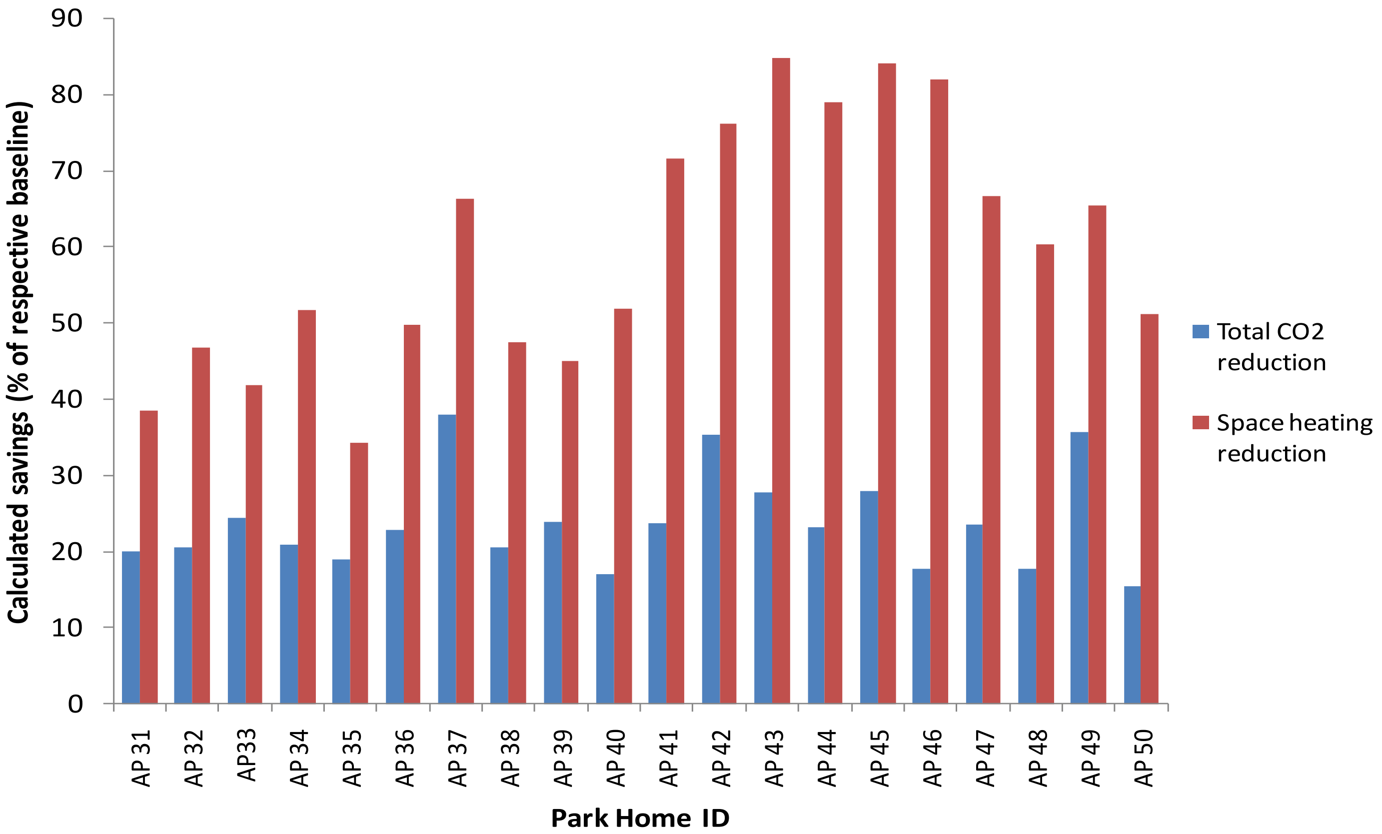
Having established the "pre and post-improvement" performance of each of the 20 Homes it was then possible to compare these TARBASE results in order to quantify the level of carbon emission reduction that had been achieved by the action, appropriate to each of the defined categories and to attribute the carbon emission savings from the insulation measures.

This follows the approach and method for typical house types and heating systems / fuels in CERT and details of the comparisons in performance levels are provided in **Appendix 4, 4A & 4B**.

On average, taken across the various categories of Park Home, the Tarbase calculations predicted a 60% reduction in space heating for the BLUE-FLAG system and an average 68% for the PARACLAD system. These equate to annual savings in CO2 emission levels of between 0.50 to 1.31 tonnes and a lifetime saving (30 years) of between 15.0 and 39.3 tonnes CO2 for each Home.

As summarised in **Figure 7** below, **Figure 8** (page 42), **Table 8** (page 40) and **Table 9** (page 41), the TARBASE comparisons show that a significant reduction in carbon emissions, space heating and energy usage has been delivered "post-improvement" across all the 20 Park Homes and that, whilst there is a variation between the benefits delivered by the Blue Flag and Paraclad insulation systems both deliver meaningful CO2 savings.

Figure 7 : Modeled CO_2 savings of dwellings compared to baseline



The estimated CO_2 savings for each dwelling is shown **(in blue)** as a percentage compared to the total baseline CO_2 emissions. The reduction ranges from 15% to 38% with an average of 24%.

The reduction in space heating is shown **(in red)** and ranges from 85% to 34% with an average of 60%.

NB : The modeled savings may be effected by occupant "take-back" and other lifestyle changes.

Table 8 : Pre v Post CO2 & Space Heating Overview

AP Ref	Improvement System	PRE Improvement CO2 Emissions BASELINE DATA		Post Improvement CO2 Emissions POST DATA		CO2 Emission Savings BASELINE (Pre) v POST		% Contribution			% Reduction Space Heating	Total Lifespan CO2 Savings 30 Years
		tCO2 / Yr	kgCO2 / m2	tCO2 / Yr	kgCO2 / m2	tCO2 / Yr	kgCO2 / m2	Walls	Roof	Floor		
AP 31	Blue Flag	2.85	89.93	2.28	71.95	0.57	17.98	81.8	0.0	18.2	38.55	17.1
AP 32	Blue Flag	2.60	43.40	2.06	34.47	0.53	8.93	59.7	27.0	13.3	46.82	16.0
AP 33	Blue Flag	4.19	69.42	3.17	52.47	1.02	16.95	75.1	0.0	24.9	41.84	30.7
AP 34	Blue Flag	3.12	64.96	2.47	51.38	0.65	13.58	66.9	13.9	19.2	51.70	19.6
AP 35	Blue Flag	3.35	82.38	2.72	66.73	0.64	15.65	80.1	0.0	19.9	34.28	19.1
AP 36	Blue Flag	3.70	52.82	2.85	40.78	0.84	12.05	52.0	19.1	28.8	49.83	25.3
AP 37	Blue Flag	5.99	74.72	3.72	46.39	2.27	28.33	48.8	34.8	16.4	66.38	68.1
AP 38	Blue Flag	2.36	68.40	1.88	54.31	0.49	14.09	62.6	23.9	13.6	47.47	14.6
AP 39	Blue Flag	3.98	84.55	3.03	64.30	0.95	20.24	47.7	31.8	20.5	45.09	28.6
AP 40	Blue Flag	2.82	44.77	2.34	37.14	0.48	7.63	52.7	34.6	12.7	51.94	14.4
AP 41	Paraclad	3.28	45.58	2.51	34.81	0.78	10.78	43.6	30.0	26.4	71.55	23.3
AP 42	Paraclad	2.84	101.25	1.83	65.48	1.00	35.78	59.6	31.9	8.5	76.27	30.1
AP 43	Paraclad	3.76	68.41	2.72	49.37	1.05	19.04	39.9	37.0	23.2	84.82	31.4
AP 44	Paraclad	2.78	69.51	2.14	53.46	0.64	16.05	39.3	44.4	16.3	78.96	19.3
AP 45	Paraclad	2.64	67.63	1.90	48.77	0.74	18.86	50.4	34.4	15.3	84.11	22.1
AP 46	Paraclad	2.75	56.16	2.26	46.22	0.49	9.94	59.7	25.7	14.5	81.94	14.6
AP 47	Paraclad	3.67	44.17	2.80	33.76	0.86	10.41	34.8	38.9	26.3	66.75	25.9
AP 48	Paraclad	3.42	42.27	2.82	34.76	0.61	7.51	39.7	36.4	23.8	60.37	18.2
AP 49	Paraclad	3.01	77.25	1.94	49.64	1.08	27.61	59.5	31.0	9.4	65.46	32.3
AP 50	Paraclad	3.02	49.52	2.56	41.90	0.46	7.62	67.6	0.0	32.4	51.18	13.9

Table 9 : Reduction in Space Heating & Energy Usage

BS Standard	Reference		U-Value W/m^2K Wall	Floor	Roof	ACH	KgCO2/m2	t/CO2/yr.	Space Heating Reduction % kWh/ m2
BS 3632: 1970	BS 3632: 1970		1.700	1.700	1.700	-	-	-	-
	Alba Measured 100 (Average)		1.890	1.405	1.083	0.82	97.70	3.27	-
	Blue Flag	Pre	1.272	0.919	0.680	0.65	69.70	4.43	-
	Blue Flag	Post	0.317	0.320	0.433	0.45	50.80	3.12	53 %
	Paraclad	Pre	1.332	0.793	1.121	0.74	70.25	2.60	-
	Paraclad	Post	0.293	0.290	0.306	0.44	53.31	2.10	78 %
BS 3632: 1981 & BS 3632: 1989	BS 3632: 1981 / 1989		1.000	1.000	0.600	-	-	-	-
	Alba Measured 100 (Average)		1.406	1.079	1.005	0.70	89.40	3.218	-
	Blue Flag	Pre	0.817	0.623	0.560	0.63	70.47	3.18	-
	Blue Flag	Post	0.302	0.338	0.413	0.41	55.87	2.52	45 %
	Paraclad	Pre	0.797	0.605	0.970	0.74	59.51	2.90	-
	Paraclad	Post	0.296	0.222	0.435	0.40	47.68	2.35	65 %
BS 3632: 1995	BS 3632: 1995		0.600	0.600	0.400	-	-	-	-
	Alba Measured 100 (Average)		0.900	0.768	0.690	0.58	70.00	3.144	-
	Blue Flag	Pre	0.624	0.421	0.437	0.56	43.40	2.60	-
	Blue Flag	Post	0.204	0.350	0.291	0.31	31.48	2.06	47 %
	Paraclad	Pre	0.629	0.495	0.450	0.44	47.04	3.28	-
	Paraclad	Post	0.229	0.206	0.196	0.25	37.39	2.60	70%
BS 3632: 2005	BS 3632: 2005		0.500	0.500	0.350	-	-	-	-
	Alba Measured 100 (Average)		0.680	0.384	0.635	0.31	65.28	3.00	
	Blue Flag	Pre	0.680	0.384	0.635	0.31	65.28	3.00	
	Blue Flag	Post	0.238	0.268	0.540	0.25	54.57	2.37	39%
	Paraclad	Pre	0.680	0.384	0.635	0.31	65.28	3.00	
	Paraclad	Post	0.272	0.177	0.292	0.18	50.20	2.18	44%

Figure 8: ***Overview of space heating savings for refurbished Park Homes***
Red = minimum in category; Blue = maximum

Category of building	Park home	% reduction in space heating	Average for that category
1970, Blue Flag	AP 33	42	53.3
	AP 34	52	
	AP 37	66	
1970, Parasol	AP 42	76	77.5
	AP 43	85	
	AP 45	84	
	AP 49	65	
1981, Blue Flag	AP 31	39	44.5
	AP 35	34	
	AP 36	50	
	AP 38	47	
	AP 39	45	
	AP 40	52	
1981, Parasol	AP 44	79	65.0
	AP 50	51	
1995, Blue Flag	AP 32	47	47.0
1995, Parasol	AP 41	71	70.0
	AP 46	82	
	AP 47	67	
	AP 48	60	

Blue Flag "Pre v "post improvement"" Thermographic Data

Following installation of the Blue Flag insulation system, a comprehensive post-improvement external infrared thermal imaging survey of 10 park homes (AP 31 – 40) was undertaken in order to assess the "as-built" thermal insulation performance of the external envelope and to compare and quantify the level of improvement that had been achieved.

The thermographic inspection data "pre-improvement" had identified areas where significant heat loss was occurring across the envelope and that this could be attributed to thermal bridging across the timber frame construction and to a number of unintentional warm-air leakage / cold air ingress pathways at critical junction details.

It was also seen that heat loss was occurring across the floors.

The thermographic inspection data "post-improvement" confirms that the Blue Flag Insulation system has delivered an improved level of thermal insulation performance across the envelope and that the numbers of unintentional heat loss pathways across the building fabric have been significantly reduced.

See Pages 44 to 45 and **Appendix 4C** for the Blue Flag "Pre v Post" Thermographic Data

Paraclad "Pre v "post improvement"" Thermographic Data

The thermographic inspection data "pre-improvement" had identified areas where significant heat loss was occurring across the envelope and that this could be attributed to thermal bridging across the timber frame construction and to a number of unintentional warm-air leakage / cold air ingress pathways at critical junction details.

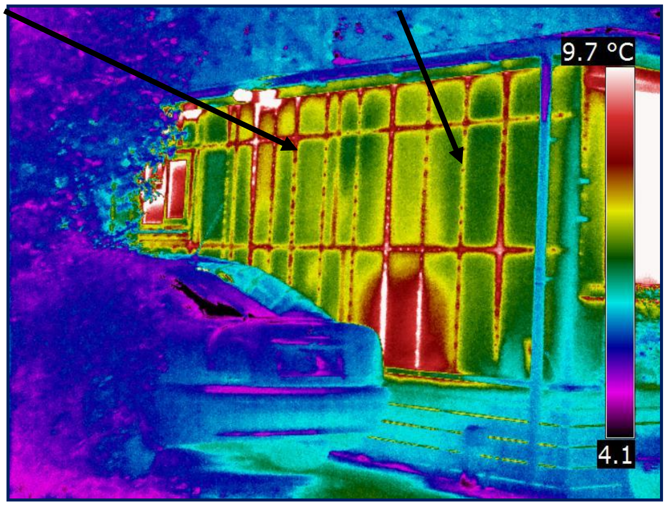
It was also seen that heat loss was occurring across the floors.

The thermographic inspection data "post-improvement" confirms that the Paraclad Insulation system has delivered an improved level of thermal insulation performance across the envelope and that the numbers of unintentional heat loss pathways across the building fabric have been significantly reduced.

See Pages 46 to 47 and **Appendix 4D** for the Paraclad "Pre v Post" Thermographic Data

Blue Flag System

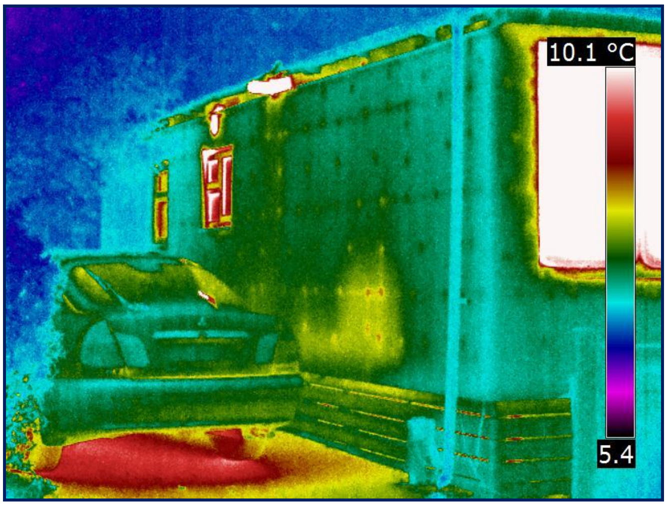
"Pre-Improvement" Inspection



In the thermal image "pre-improvement", it is clear that significant heat loss is occurring across the building envelope and that this can be attributed to thermal bridging across the timber frame construction in addition to warm air leakage at critical junction details.

The thermographic inspection also identified a number of anomalies that were indicative of heat loss occurring across the floor construction.

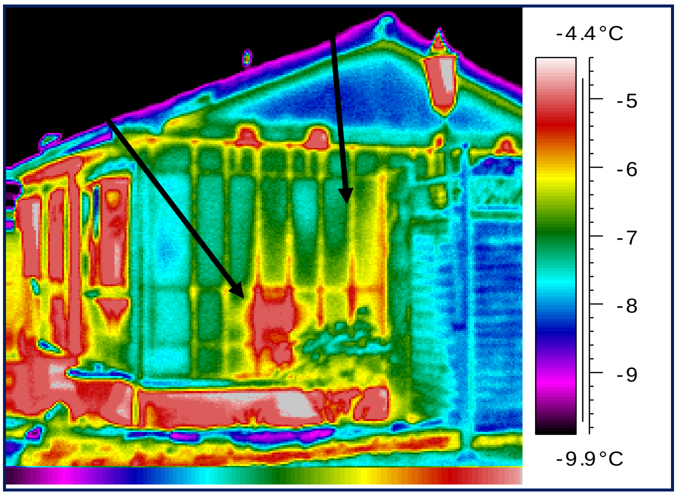
"Post-Improvement" Inspection



It can be seen in the above thermal image "post-improvement" that the number of heat-loss pathways across the building envelope have been significantly reduced (i.e. when compared to the "pre-improvement" image).

Blue Flag System

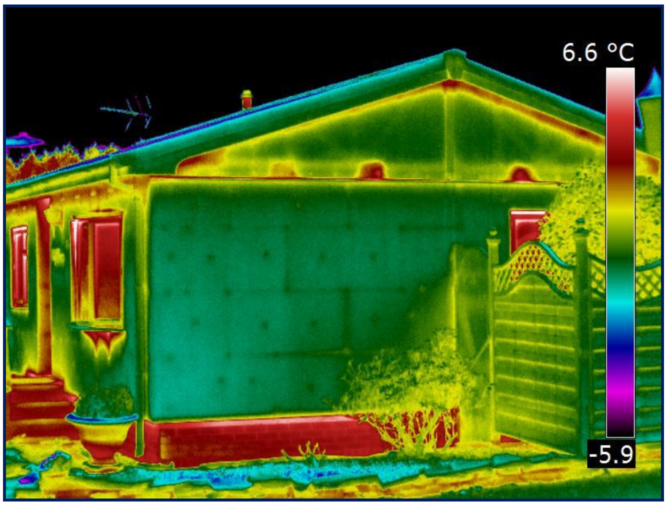
"Pre-Improvement" Inspection



In the thermal image "pre-improvement", it is clear that significant heat loss is occurring across the building envelope and that this can be attributed to thermal bridging across the timber frame construction in addition to warm air leakage at critical junction details.

The thermographic inspection also identified a number of anomalies that were indicative of heat loss occurring across the floor construction.

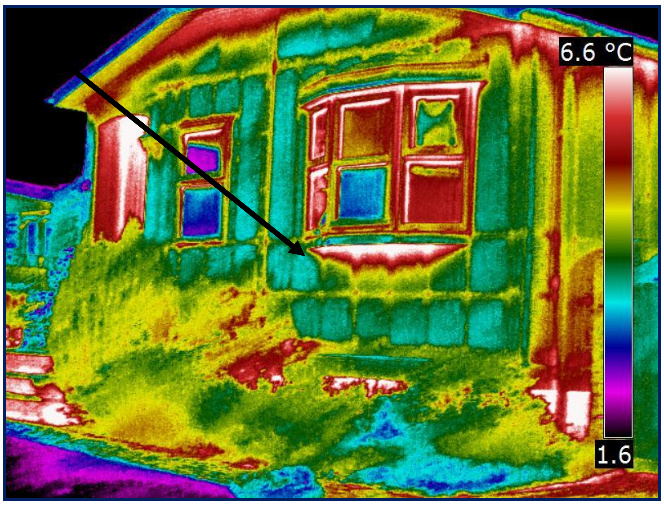
"Post-Improvement" Inspection



It can be seen in the above thermal image "post-improvement" that the number of heat-loss pathways across the building envelope have been significantly reduced (i.e. when compared to the "pre-improvement" image).

Paraclad System

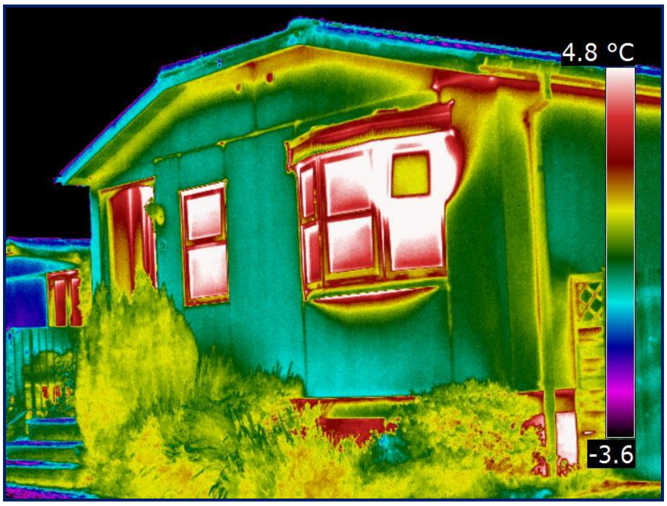
"Pre-Improvement" Inspection



In the thermal image "pre-improvement", it is clear that significant heat loss is occurring across the building envelope and that this can be attributed to thermal bridging across the timber frame construction in addition to warm air leakage at critical junction details.

The thermographic inspection also identified a number of anomalies that were indicative of heat loss occurring across the floors.

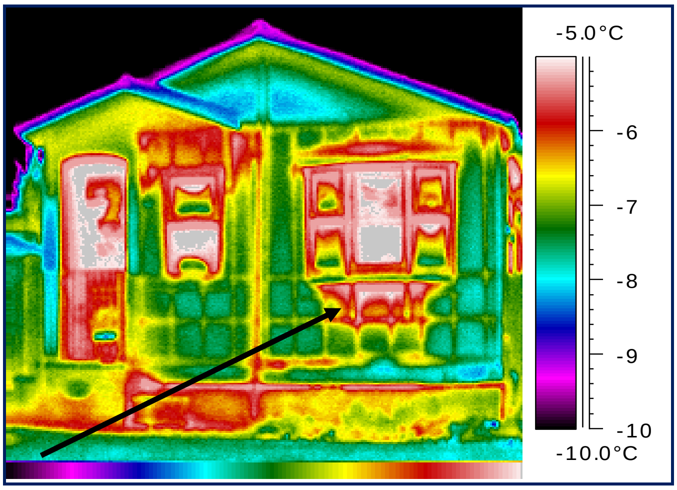
"Post-Improvement" Inspection



It can be seen in the above thermal image "post-improvement" that the number of heat-loss pathways across the building envelope have been significantly reduced (i.e. when compared to the "pre-improvement" image)

Paraclad System

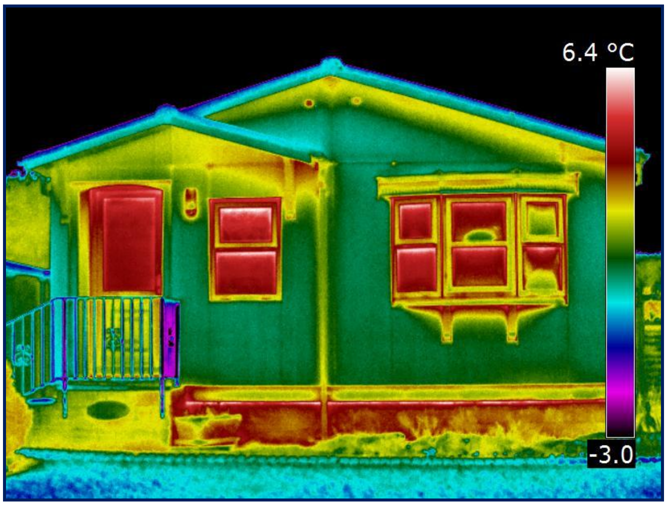
"Pre improvement" Inspection



In the thermal image "pre-improvement", it is clear that significant heat loss is occurring across the building envelope and that this can be attributed to thermal bridging across the timber frame construction in addition to warm air leakage at critical junction details.

The thermographic inspection also identified a number of anomalies that were indicative of heat loss occurring across the floor construction.

"Post improvement" Inspection



It can be seen in the above thermal image "post-improvement" that the number of heat-loss pathways across the building envelope have been significantly reduced (i.e. when compared to the pre-improvement image)

Post Monitoring

Pilot Project

As detailed earlier within **(Page 18)** of this report, an initial step in the Demonstration Action was for a pilot project to be undertaken on a few Park Homes located on a site in Nottingham which trialed the installation of lightweight "Paraclad" insulated wall panels together with a range of other insulation improvements to the under-floors and roofs.

The data obtained from this pilot "pre and post-improvement" was input into the TARBASE calculation model in order to ascertain the CO2 savings that had been delivered by the insulation improvements and assisted in the selection, for the main project, of the most suitable refurbishment "mix" of insulation for the floors, walls and roofs taking into account the practicalities of installation, the resultant thermal insulation performance benefits and value for money.

Monitoring of the actual "post-improvement" energy usage and occupier lifestyle influences was undertaken over the winter period November 2009 to May 2010 and confirmed that significant savings both in terms of reduced expenditure on space heating (average 28%) and on electric energy consumption (average 18%) were being realised whilst average internal temperatures rose by 2.8ºC

Main Project

Following-on from the pilot, the main project involved "pre-improvement" assessments of 100 Park Homes sited at various locations across the country, from which two groups of 10 homes were selected, on the basis that they provided a representative sample of UK Park Home stock. Two different types of lightweight external wall insulation systems, "Blue Flag" and "Paraclad", were installed across these two groups, together with insulation of the under-floors and roofs.

On completion of the insulation improvements, the two groups of ten homes were subjected to a "post-improvement" performance assessment by repeating the scientific techniques used for the "pre-improvement" measurements. A post-improvement occupier questionnaire was also compiled for each.

The performance data relating to the post-improvement assessments was input into TARBASE in order to establish the carbon emission levels applicable across the various categories of Park Home contained within the two groups of 10.

Monitoring of the actual "pre and post-improvement" internal living space temperatures and occupier lifestyle influences was undertaken over the winter periods November 2009 to May 2010 (pre) and 2010/2011 (post) together with an audit of the utility bills and actual fuel usage for each home.

The "pre-improvement" monitoring data produced a daytime average temperature of 19ºC for the heated living spaces proving that, prior to the action, many homes were not being heated to a reasonable internal comfort level. The "post-improvement" data produced a higher daytime average temperature of 22.5ºC.

The audit of actual costs also confirmed that an average combined saving of 37.5% on space heating and electricity was achieved across the 20 homes whilst the average internal temperatures rose by 3.5ºC.

The following section of this report details the actual "pre and post-improvement" space heating and electricity costs for both Blue Flag and Paraclad systems for each of the 20 homes.

Blue Flag – Actual Energy Costs Pre v Post Improvement

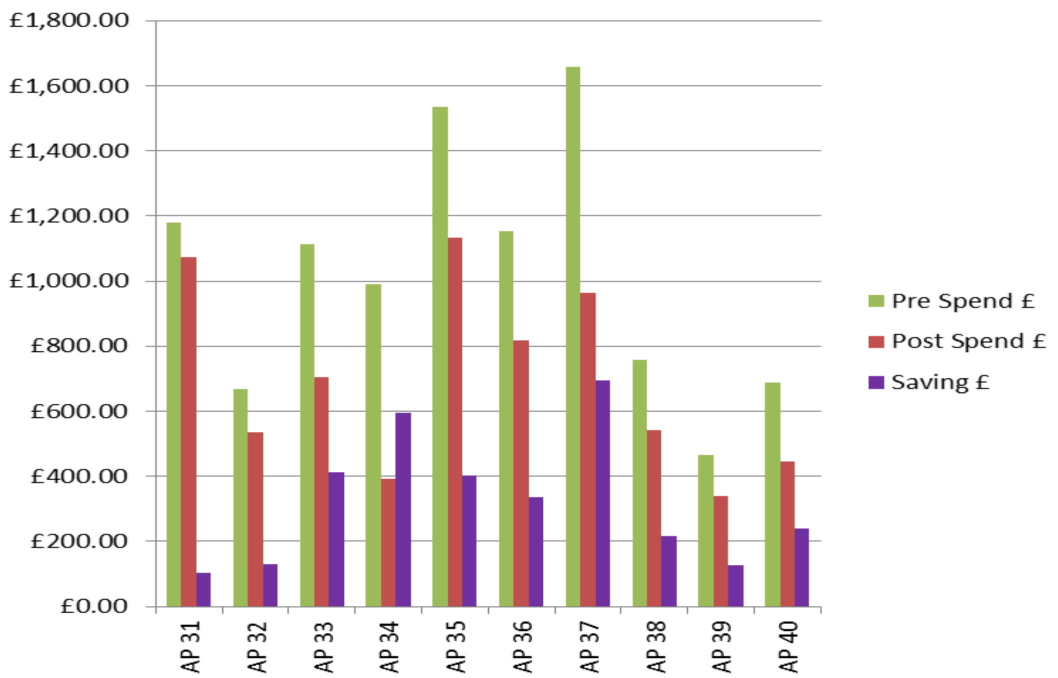
The audit of actual costs "post-improvement" confirmed that significant savings were being realised across the group of 10 homes insulated with the Blue Flag system. A reduction in fuel usage was accompanied by reduced expenditure on space heating and on electric energy consumption. A synopsis of the savings applicable to each home is presented below and a full analysis **provided in Appendix 6.**

Table 10: Blue Flag Summary Average Savings Pre v Post Improvement.

Blue Flag AP 31 - 40	Average Savings (Pre v Post Improvement)	
	£ Cost Saving as %	Consumption Saving as %
Heating / Fuel	35 %	39 %
Electricity	12 %	11 %
An average combined Heat & Power £ cost saving of 31 %		

Table 11: Blue Flag Combined Energy (Heat & Power) Costs "Pre v Post-Improvement"

REF	Combined Actual Cost Pre Improvement	Combined Actual Cost Post Improvement	Combined Cost Saving	
	Nov 09 - May 10	Nov 10 - May 2011	£	%
AP 31	£1,179.89	£1,074.69	£105	9%
AP 32	£668.20	£536.76	£131	20%
AP 33	£1,114.53	£703.21	£411	37%
AP 34	£988.65	£392.66	£596	60%
AP 35	£1,534.22	£1,132.80	£401	26%
AP 36	£1,152.19	£817.66	£335	29%
AP 37	£1,657.00	£963.22	£694	42%
AP 38	£758.33	£541.19	£217	29%
AP 39	£465.94	£338.45	£127	27%
AP 40	£688.00	£447.18	£241	35%

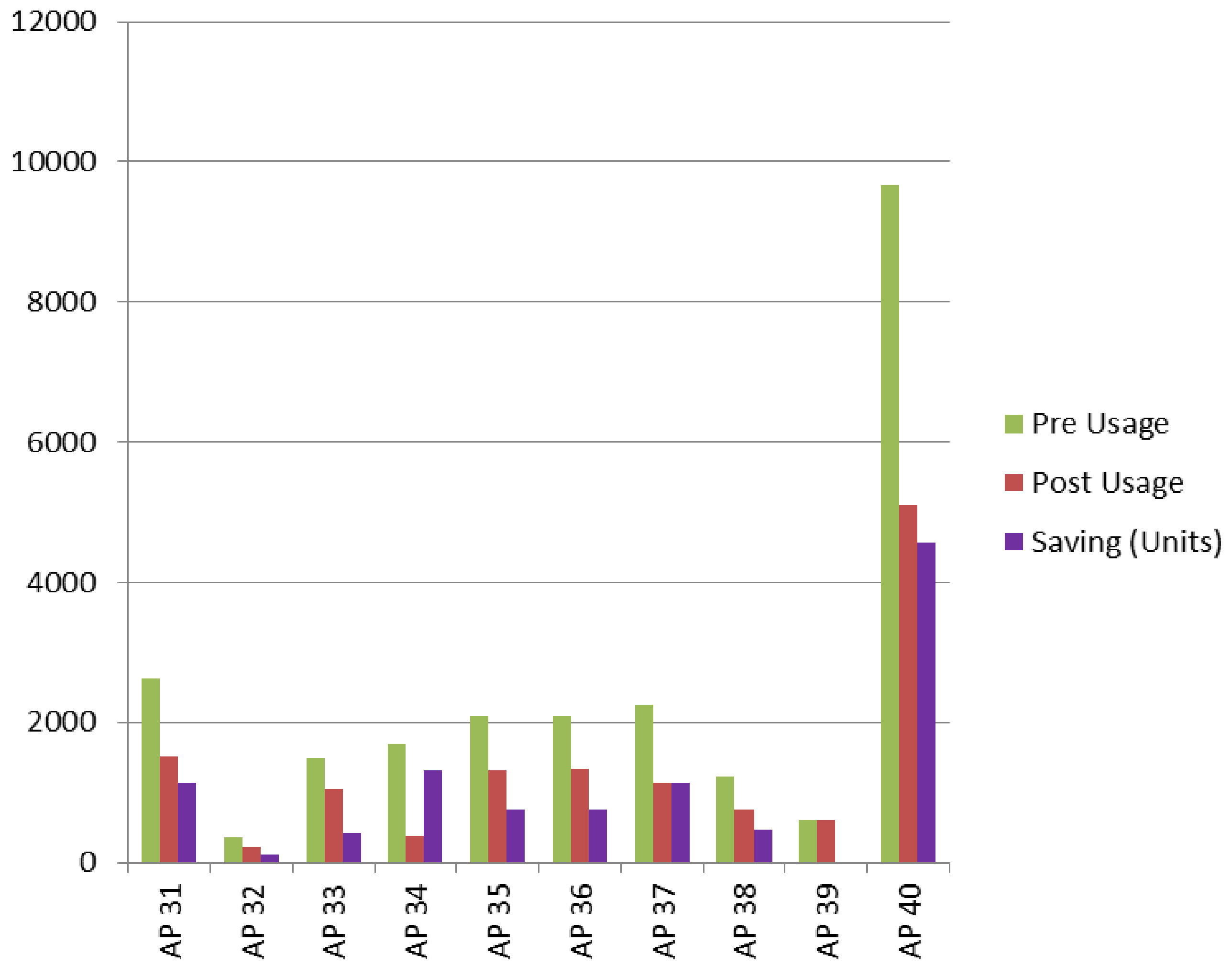


Blue Flag

Table 12 : Blue Flag Fuel (Heating) Usage, Costs & Savings "Pre v Post-Improvement"

Ref	Fuel Type	Supply	PRE IMPROVEMENT		POST IMPROVEMENT		Savings			
							Cost		Fuel Usage	
			£ Spend	Units Used	£ Spend	Units Used	£	%	Units	%
AP 31	LPG Gas	47Kg Bottles	£979.89	2632	£899.69	1505	£80.20	8%	1127	43%
AP 32	LPG Gas	Tank	£552.80	353	£419.40	233	£133.40	24%	120	34%
AP 33	LPG Gas	47Kg Bottles	£947.15	1484	£546.48	1056	£400.67	42%	428	29%
AP 34	LPG Gas	47Kg Bottles	£755.99	1692	£176.38	376	£579.61	77%	1316	78%
AP 35	LPG Gas	Tank	£1,267.77	2085	£896.72	1322	£371.05	29%	763	37%
AP 36	LPG Gas	Tank	£1,029.00	2100	£695.10	1347	£333.90	32%	753	36%
AP 37	LPG Gas	47Kg Bottles	£1,007.98	2256	£533.34	1128	£474.64	47%	1128	50%
AP 38	LPG Gas	47Kg Bottles	£559.94	1222	£362	752	£198.00	35%	470	38%
AP 39	Electric	Storage Radiators	£30.00	600	£30	600	£0.00	0%	0	0%
AP 40	Gas	Mains	£460.00	9662	£250.18	5094	£209.82	46%	4568	47%

Figure 9: Blue Flag: Fuel (Heating) Usage, Costs & Savings "Pre v Post-Improvement"



Paraclad – Actual Energy Costs Pre v Post Improvement

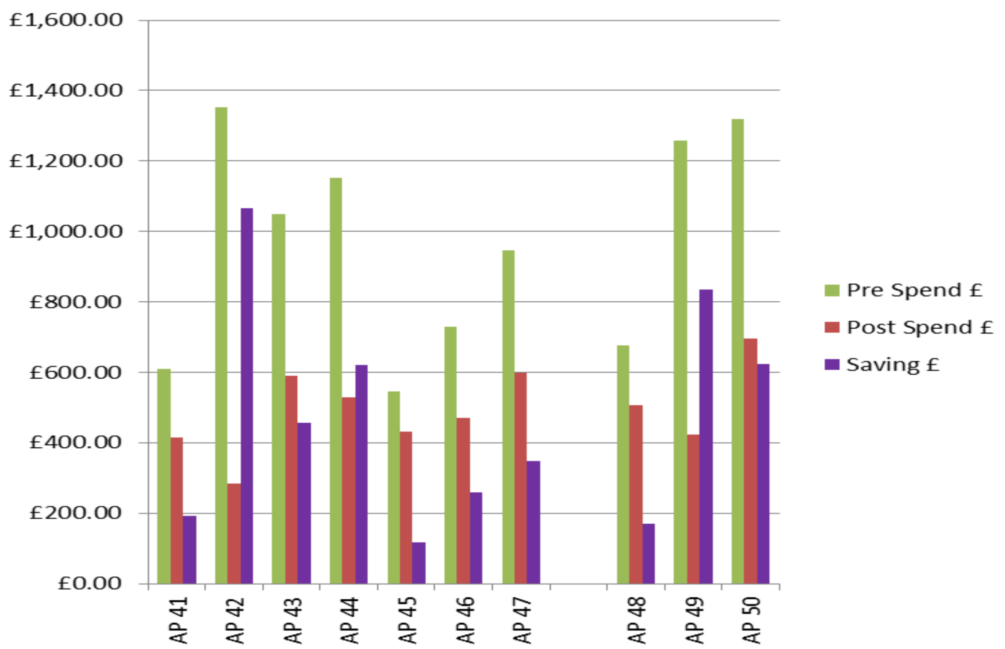
The audit of actual costs “post-improvement” confirmed that significant savings were being realised across the group of 10 homes insulated with the Paraclad system. A reduction in fuel usage was accompanied by reduced expenditure on space heating and on electric energy consumption. A synopsis of the savings applicable to each home is presented below and a full analysis **provided in Appendix 6.**

Table 13: Paraclad Summary Average Savings Pre v Post Improvement.

Paraclad AP 41 - 50	Average Savings (Pre v Post Improvement)	
	£ Cost Saving as %	Consumption Saving as %
Heating / Fuel	53 %	54 %
Electricity	11 %	12 %
An average combined Heat & Power £ cost saving of 44 %		

Table 14: Paraclad Combined Energy (Heat & Power) Costs “Pre v Post-Improvement”

REF	Combined Actual Cost Pre Improvement	Combined Actual Cost Post Improvement	Combined Cost Saving	
	Nov 09 - May 10	Nov 10 - May 2011	£	%
AP 41	£608.66	£415.70	£193	32%
AP 42	£1,351.60	£284.68	£1,067	79%
AP 43	£1,048.41	£590.59	£458	44%
AP 44	£1,152.00	£530.00	£622	54%
AP 45	£546.95	£430.96	£116	21%
AP 46	£728.54	£469.92	£259	35%
AP 47	£945.40	£598.65	£347	37%
AP 48	£676.47	£505.83	£171	25%
AP 49	£1,257.98	£423.48	£835	66%
AP 50	£1,319.29	£694.73	£625	47%

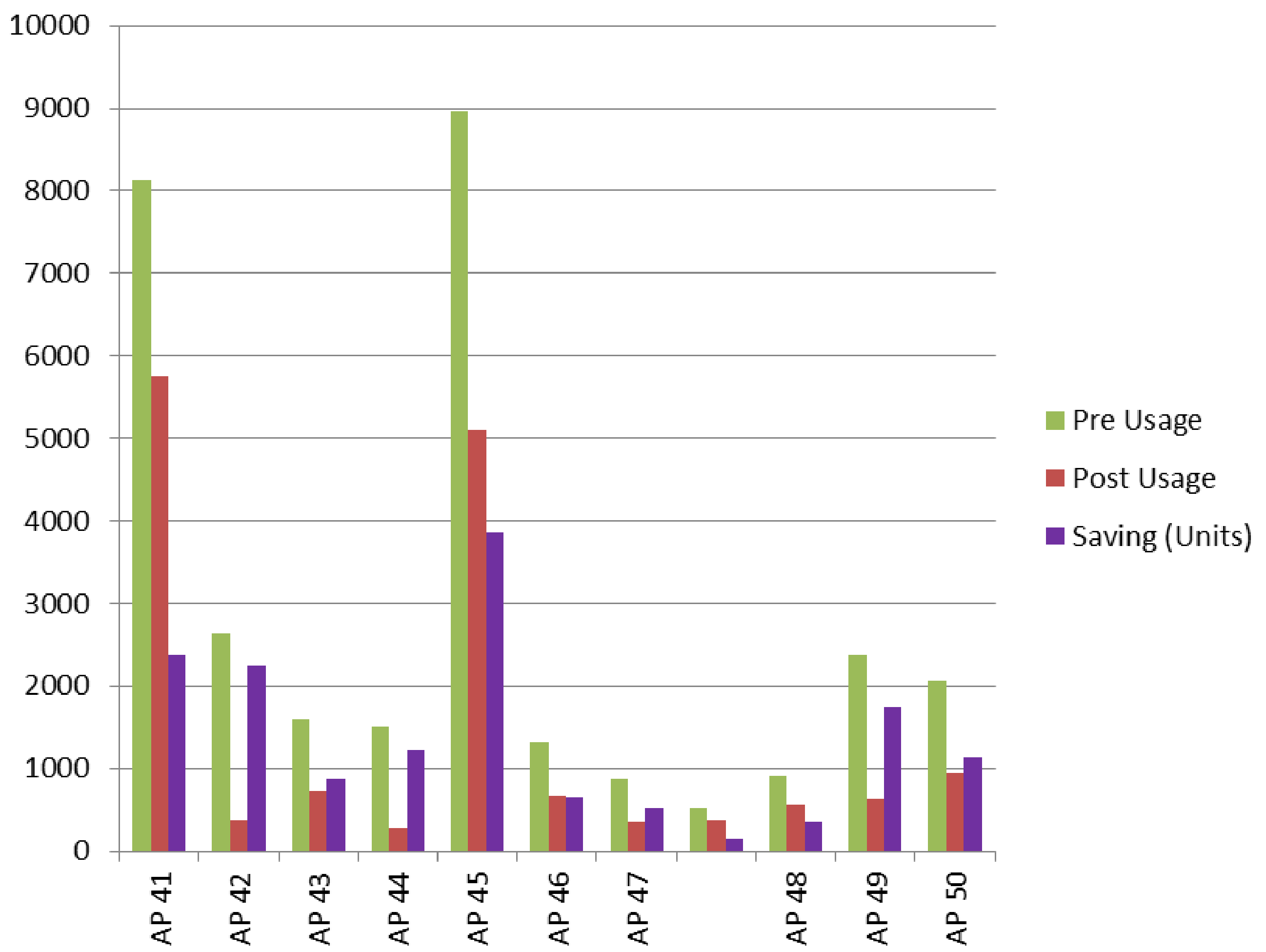


Paraclad

Table 15: Paraclad: Fuel (Heating) Usage, Costs & Savings "Pre v Post-Improvement"

Ref	Fuel Type	Supply	PRE IMPROVEMENT		POST IMPROVEMENT		Savings			
							Cost		Fuel Usage	
			£ Spend	Units Used	£ Spend	Units Used	£	%	Units	%
AP 41	Gas	Mains	£414.66	8120	£239.32	5751	£175.34	42%	2369	29%
AP 42	LPG Gas	47Kg Bottles	£1,189.93	2632	£178.00	376	£1,011.93	85%	2256	86%
AP 43	Oil	Tank	£828.42	1600	£391.25	725	£437.17	53%	875	55%
AP 44	LPG Gas	47Kg Bottles	£752.00	1504	£150.00	282	£602.00	80%	1222	81%
AP 45	LPG Gas	Tank	£389.63	8957	£248.40	5100	£141.23	36%	3857	43%
AP 46	LPG Gas	Site Tank (shared)	£570.95	1313	£329.96	670	£240.99	42%	643	49%
AP 47	LPG Gas	Site Tank (shared)	£443.17	877	£210.12	350	£233.05	53%	527	60%
		Gas Heater (Disability)	£332.50	525	£237.50	375	£95.00	29%	150	29%
AP 48	LPG Gas	Site Tank (shared)	£443.92	915	£304.00	554	£139.92	32%	361	39%
AP 49	LPG Gas	47Kg Bottles	£1,083.98	2376	£295.98	624	£788.00	73%	1752	74%
AP 50	LPG Gas	47Kg Bottles	£1,055.81	2068	£444.94	940	£610.87	58%	1128	55%

Figure 10: Paraclad: Fuel (Heating) Usage, Costs & Savings "Pre v Post-Improvement"



Actual Costs Pre v Post Analysis

As detailed above, the audit of the actual costs incurred by occupiers "post-improvement" confirmed that significant savings were being realised across the two groups of 10 homes.

A reduction in fuel usage was accompanied by reduced expenditure on space heating and on electric energy consumption.

Prior to the action it was evident that many homes were not being heated to a reasonable internal comfort level with the "pre-improvement" monitoring data producing a daytime average of 19ºC for the heated living spaces across the 20 homes

The "post-improvement" monitoring data produced a higher daytime average temperature of 22.5ºC for the heated living spaces providing evidence of "occupier take-back" which has an impact on the level of actual cost and energy savings delivered by the action.

Post Monitoring Temperature Data is provided in **Appendix 8A & 8B**.

Those savings predicted by the Tarbase calculation model were seen to broadly align with the actual cost benefits being realised by occupiers, taking into account the variations in the different categories of park home and the 3.5ºC average "take-back" in internal comfort temperatures.

The differences in actual cost savings between the Blue Flag and Paraclad systems were:-

Blue Flag

Heating / Fuel Savings: Average £ **Cost Saving 35 %** & Average **Consumption Saving 39 %**

Electricity Savings: Average £ **Cost Saving 12 %** & Average **Consumption Saving 11 %**

Combined (H & P) Savings: Average £ **Cost saving of 31 %**

Paraclad

Heating / Fuel Savings: Average £ **Cost Saving 53 %** & Average **Consumption Saving 54 %**

Electricity Savings: Average £ **Cost Saving 11 %** & Average **Consumption Saving 12 %**

Combined (H & P) Savings: Average £ **Cost saving of 44 %**

In real terms, for the six month monitoring period November 2010 to May 2011, the demonstration action has resulted in warmer, more comfortable homes with an average combined saving of £326 being realised for those homes insulated with the Blue Flag system and an average combined saving of £468 being realised for those homes insulated with the Paraclad System.

Whilst it is recognised that space heating and energy consumption over the monitored six month winter period is at its highest, it is also evident that further cost savings should accrue to occupiers over the remaining six months of the year due to the insulation improvements.

Monitoring of the 20 homes is on-going.