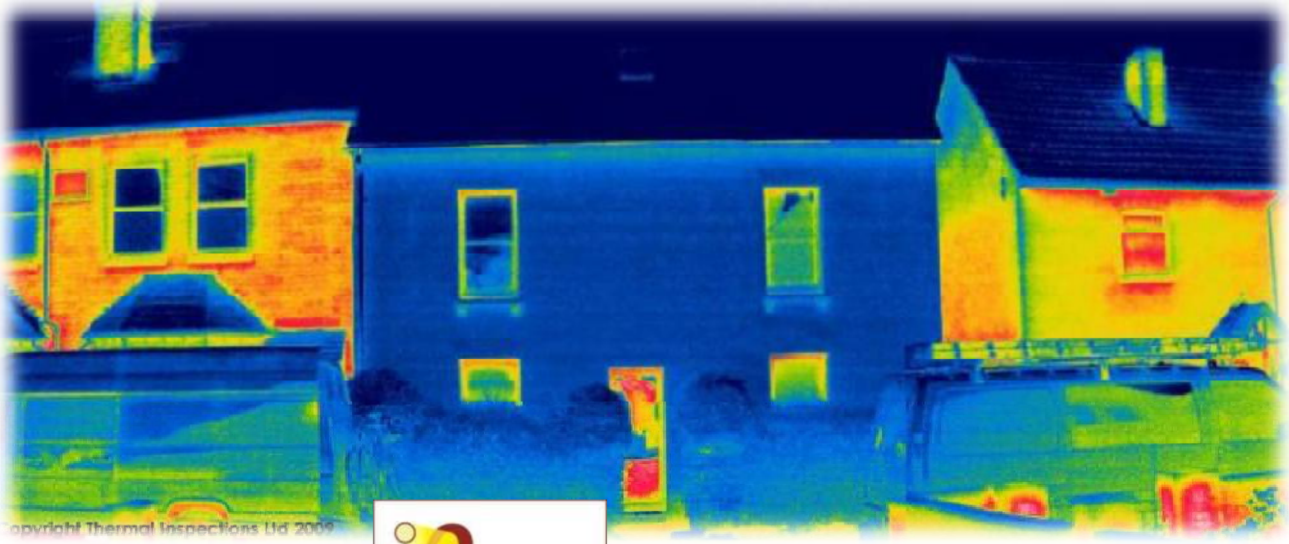
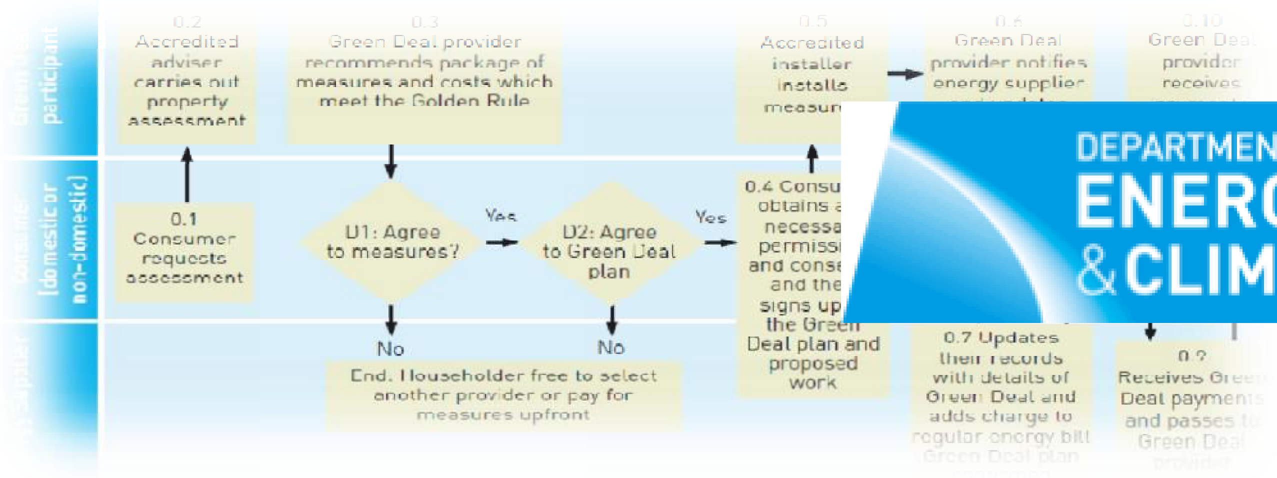


EnerPHit
Quality Approved Energy Retrofit with Passive House Components
Passive House Institute

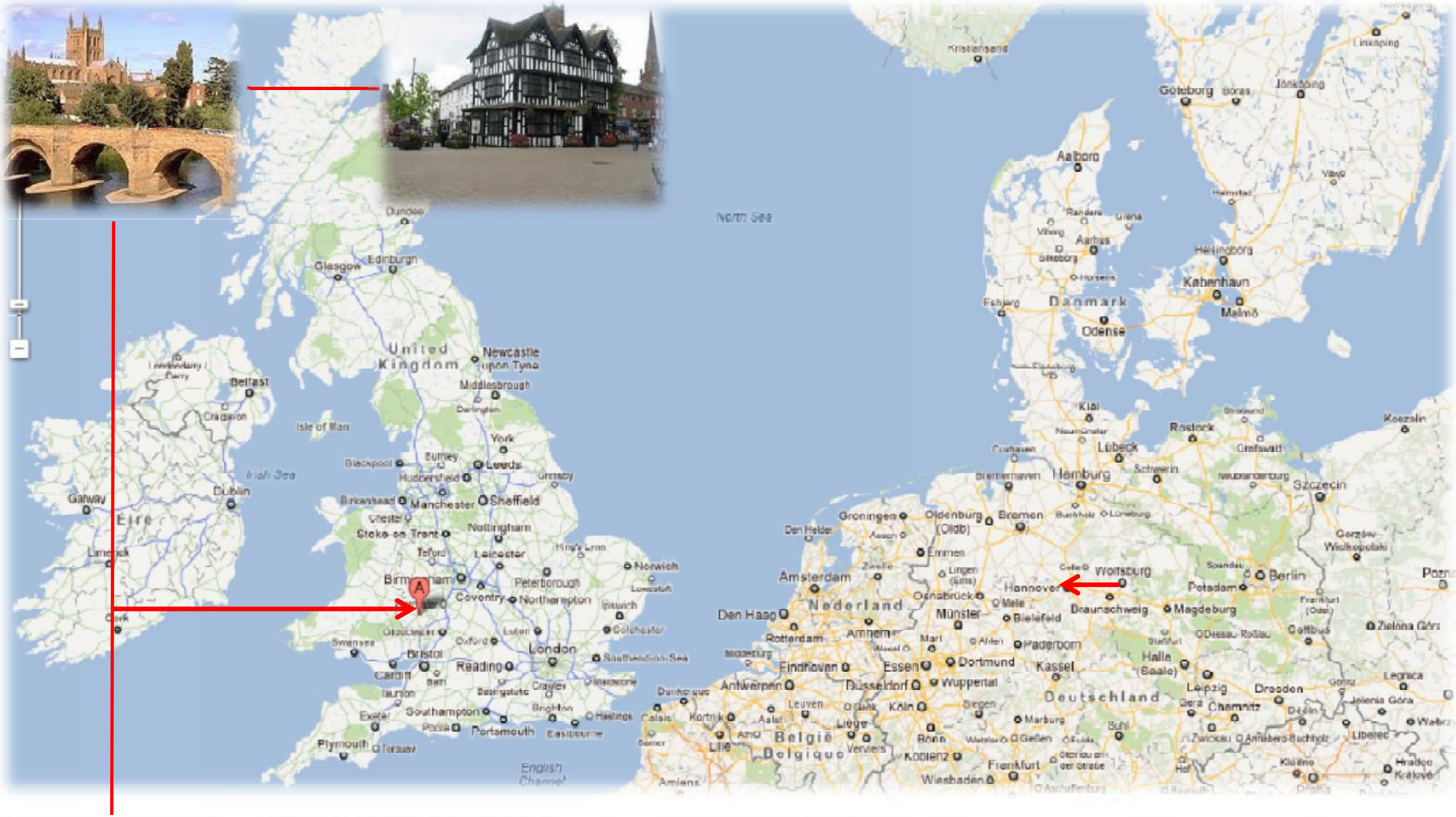
RetroPHit
affordable energy and comfort

UK EnerPHit case study: what lessons for the UK Green Deal ?



DEPARTMENT OF ENERGY & CLIMATE CHANGE

Grove Cottage, Hereford, UK

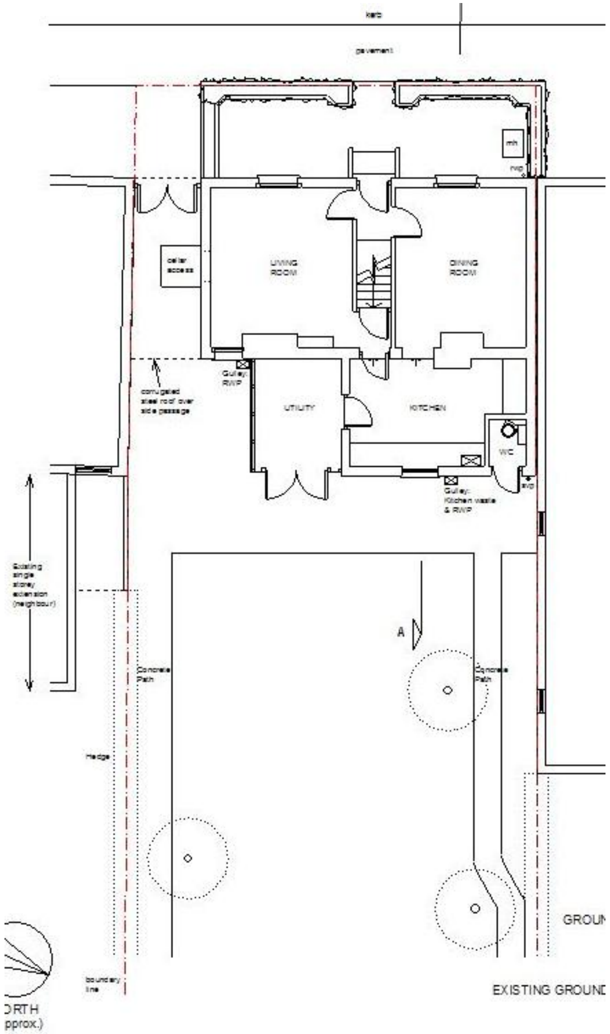


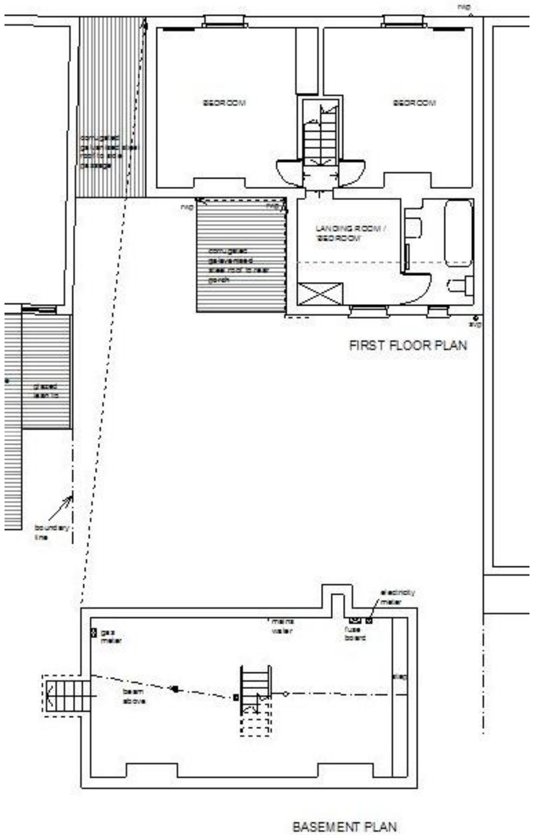
Grove Cottage before retrofit

A 90 m^2 urban solid brick house – built in 1869

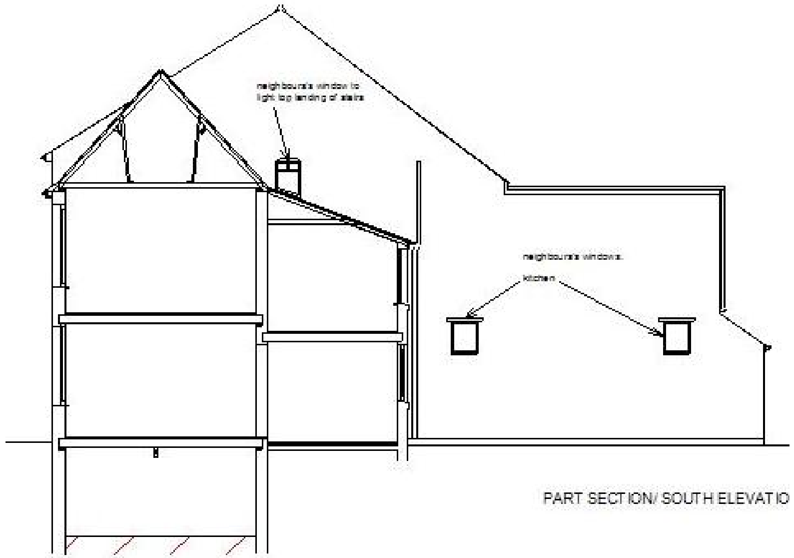
Bought in 2005

Family of five

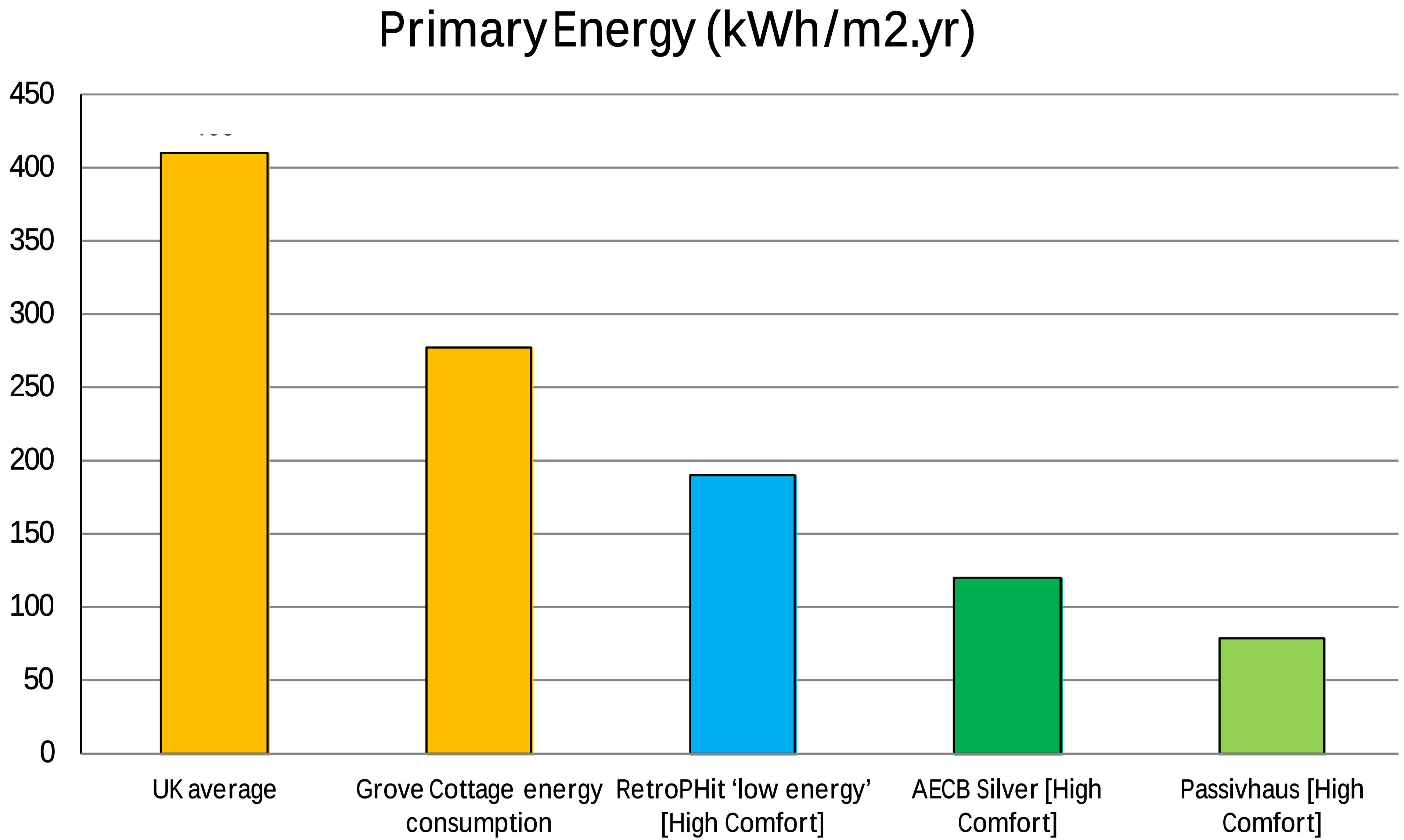




- o COLD
- o DRAUGHTY
- o EXPENSIVE
- o HIGH GHG EMISSIONS
- o POOR AIR QUALITY



MEASURED: primary Energy – before retrofit (2005)

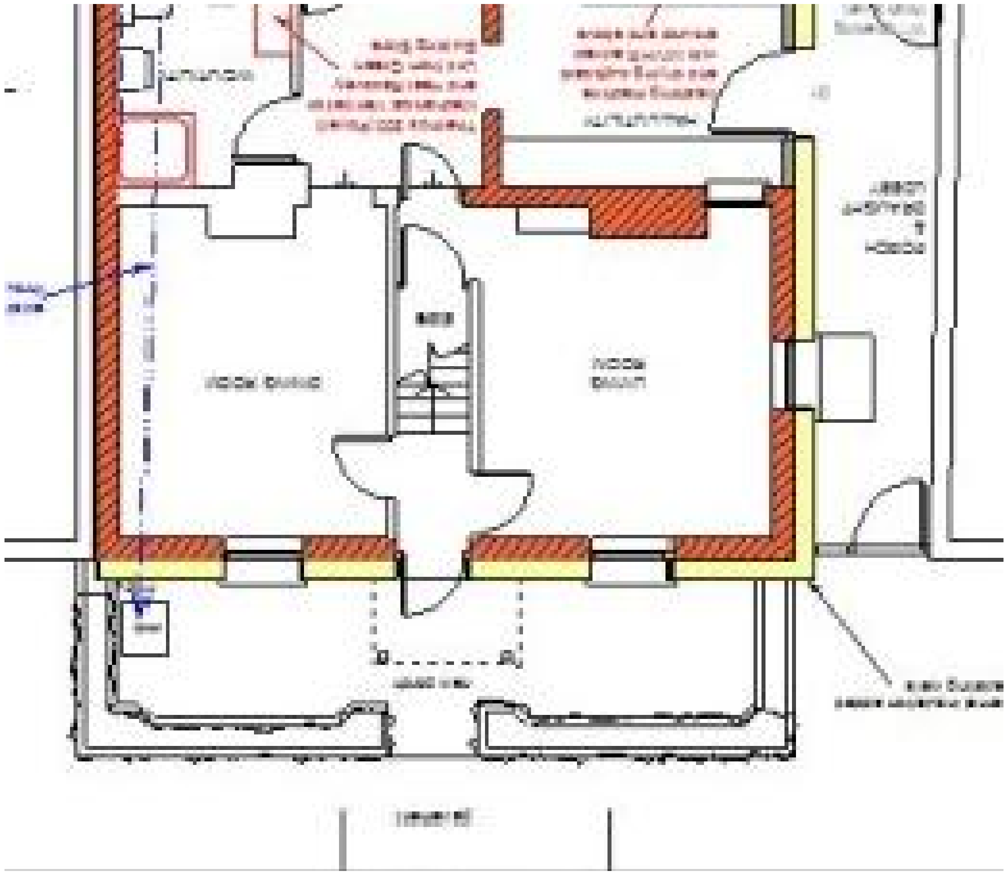


The EnerPHit measures – PHPP forecast

Treated Floor Area: **134.6** m^2

	Applied:	Monthly method	EnerPHit Certificate:	Fulfilled?
Specific Space Heating Demand:	25	$kWh/(m^2a)$	$25 kWh/(m^2a)$	Yes
Heating Load:	13	W/m^2	$10 W/m^2$	
Pressurization Test Result:	1.0	h^{-1}	$1.0 h^{-1}$	Yes
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	109	$kWh/(m^2a)$	$133 kWh/(m^2a)$	Yes
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	68	$kWh/(m^2a)$		

Grove Cottage after retrofit – street side



Grove Cottage: front elevations (West)

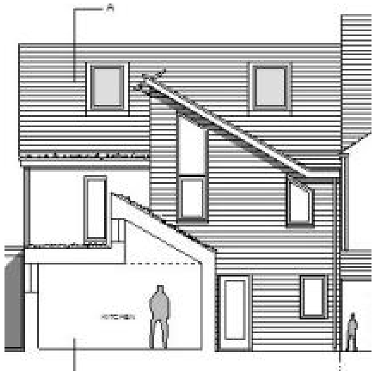
Grove Cottage after retrofit – garden side

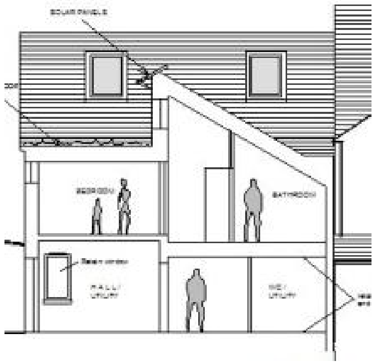
Remodelled, re-oriented roof & S-facing glazing above original brick ‘lean to’

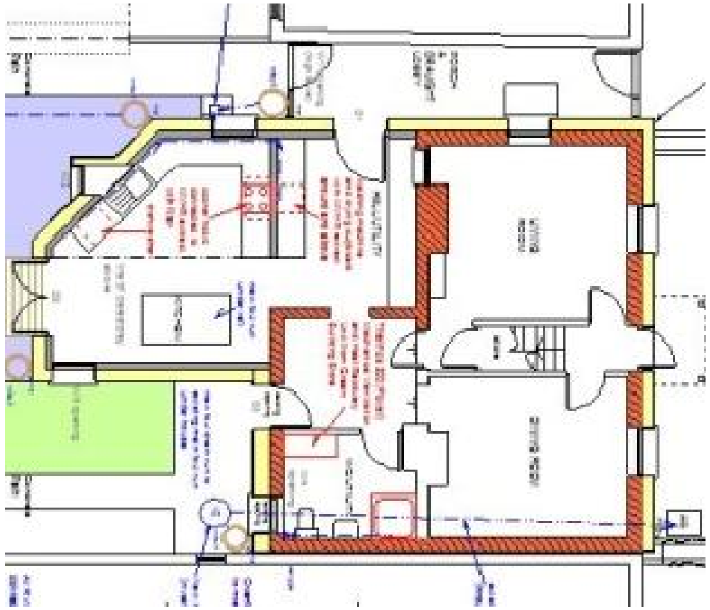
2 storey extension

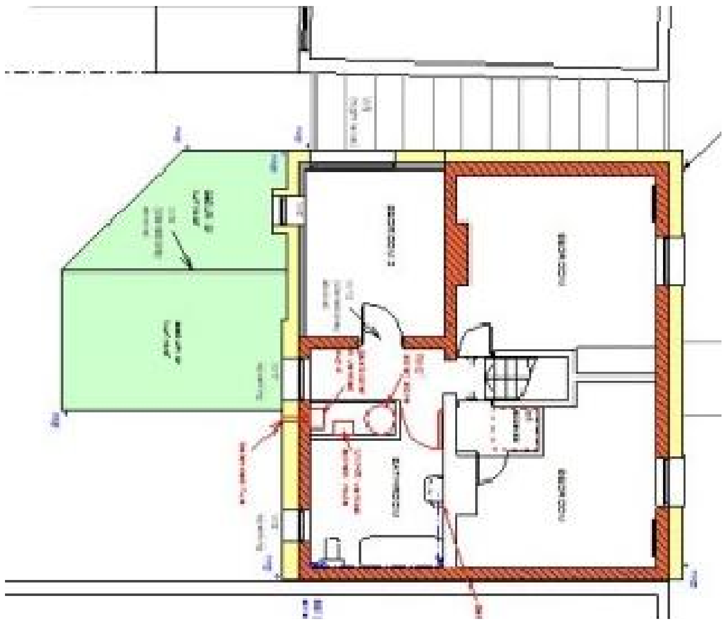
Single storey extension

Grove Cottage after retrofit – garden side









Grove Cottage: rear elevations (East)

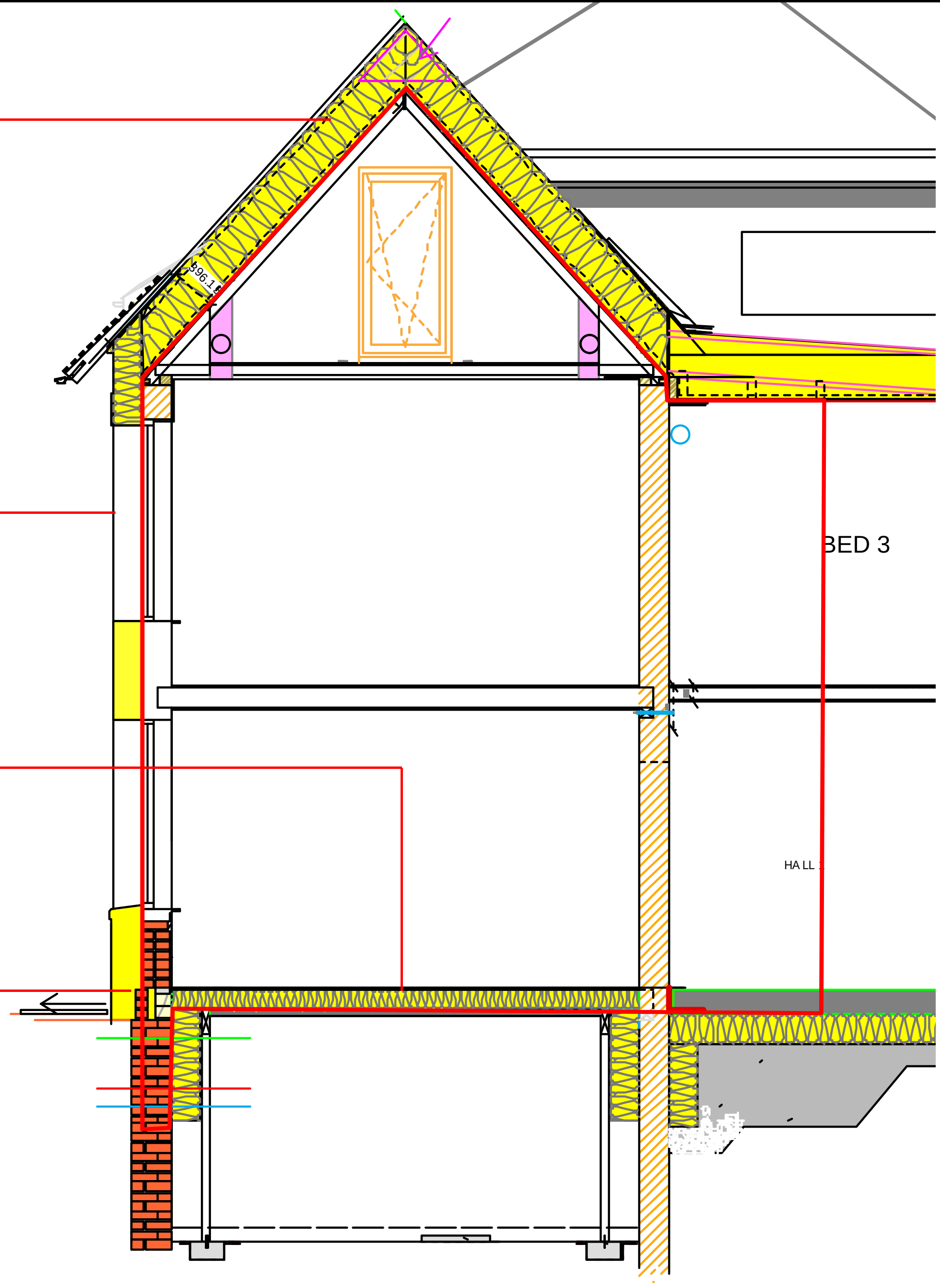
The fabric strategy

400 mm roof insulation

250 mm wall insulation

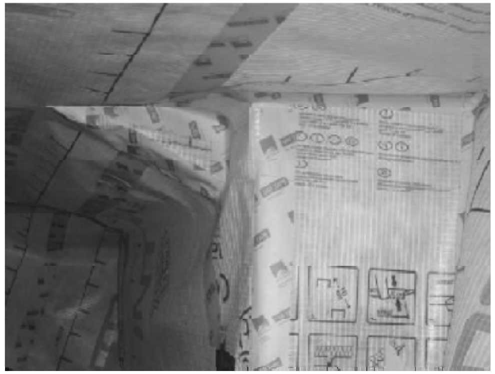
225 mm floor insulation

‘Thermal bridge free’ junctions
- where possible



The refurbishment measures



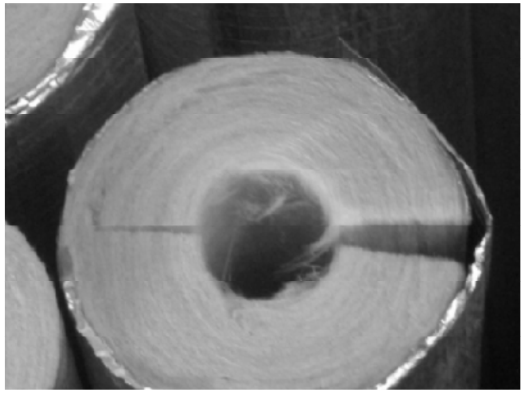



Airtightness

Ventilation

Appliances



Insulation

Money

Total spend (including sponsorship)

£140,000

- New 45 m^2 extension + attic conversion + external works:

  £95,000

- Repair & EnerPHit level retrofit of existing house:

  £45,000

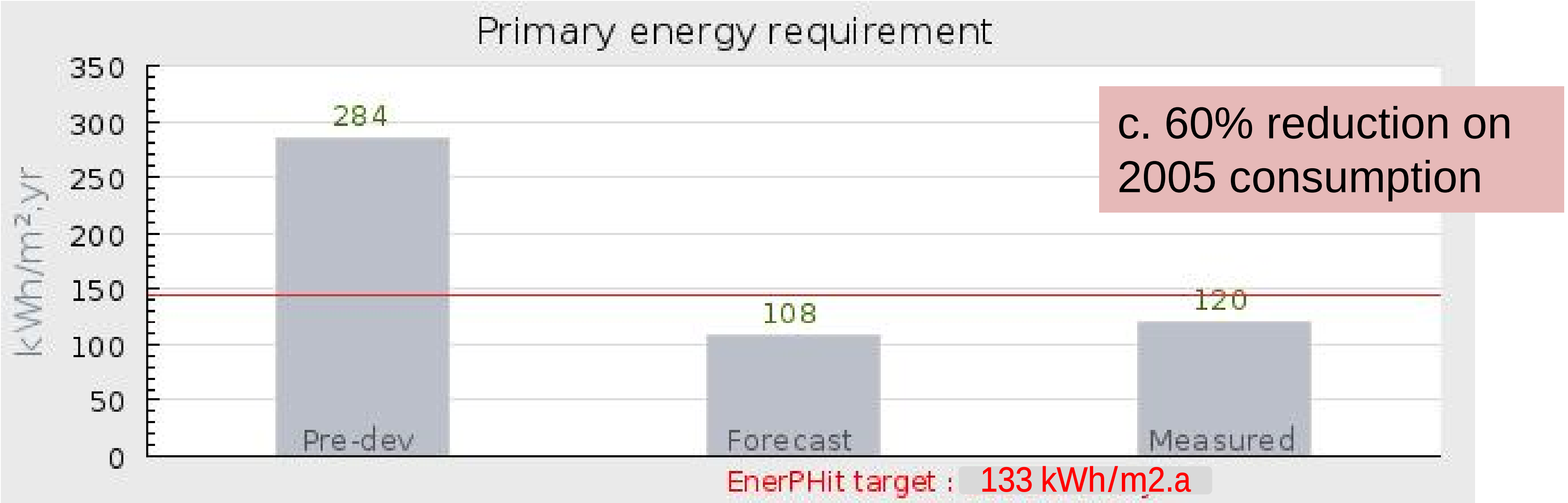
Funded through Ecology Building Society C-Change mortgage (3.9% tracker)

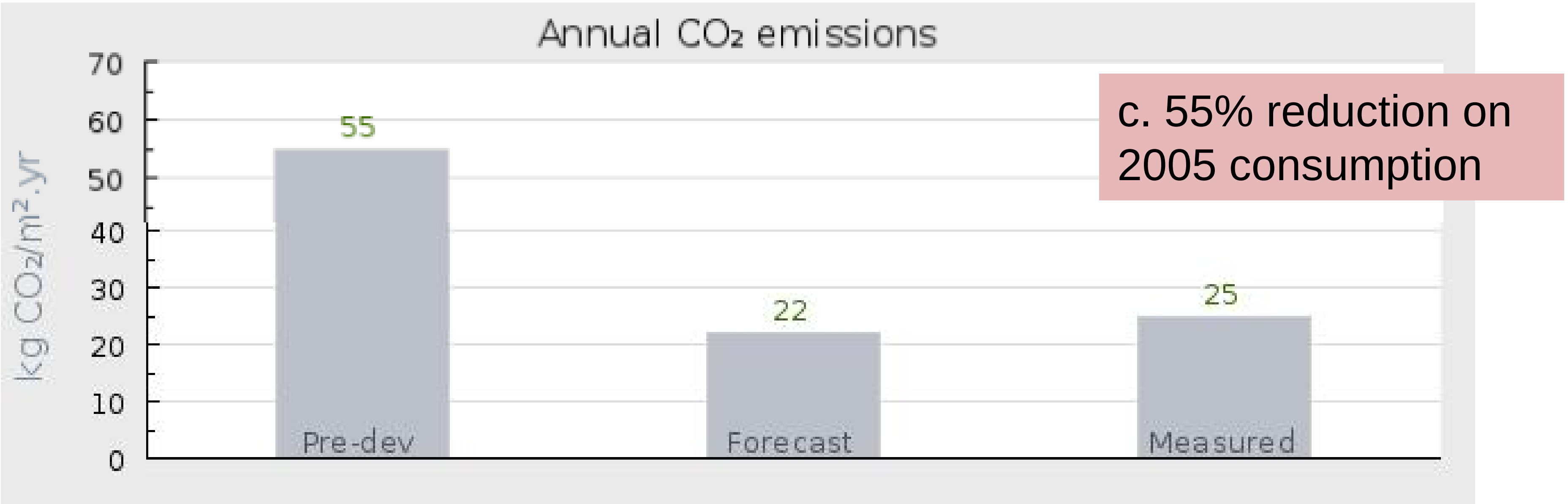
Above (on left): Grove Cottage now, after refurbishment. The house cost £165,000 to buy in 2005.

Provisional: retrofit achieved for £450 - 500/m^2

(not including design professional costs)

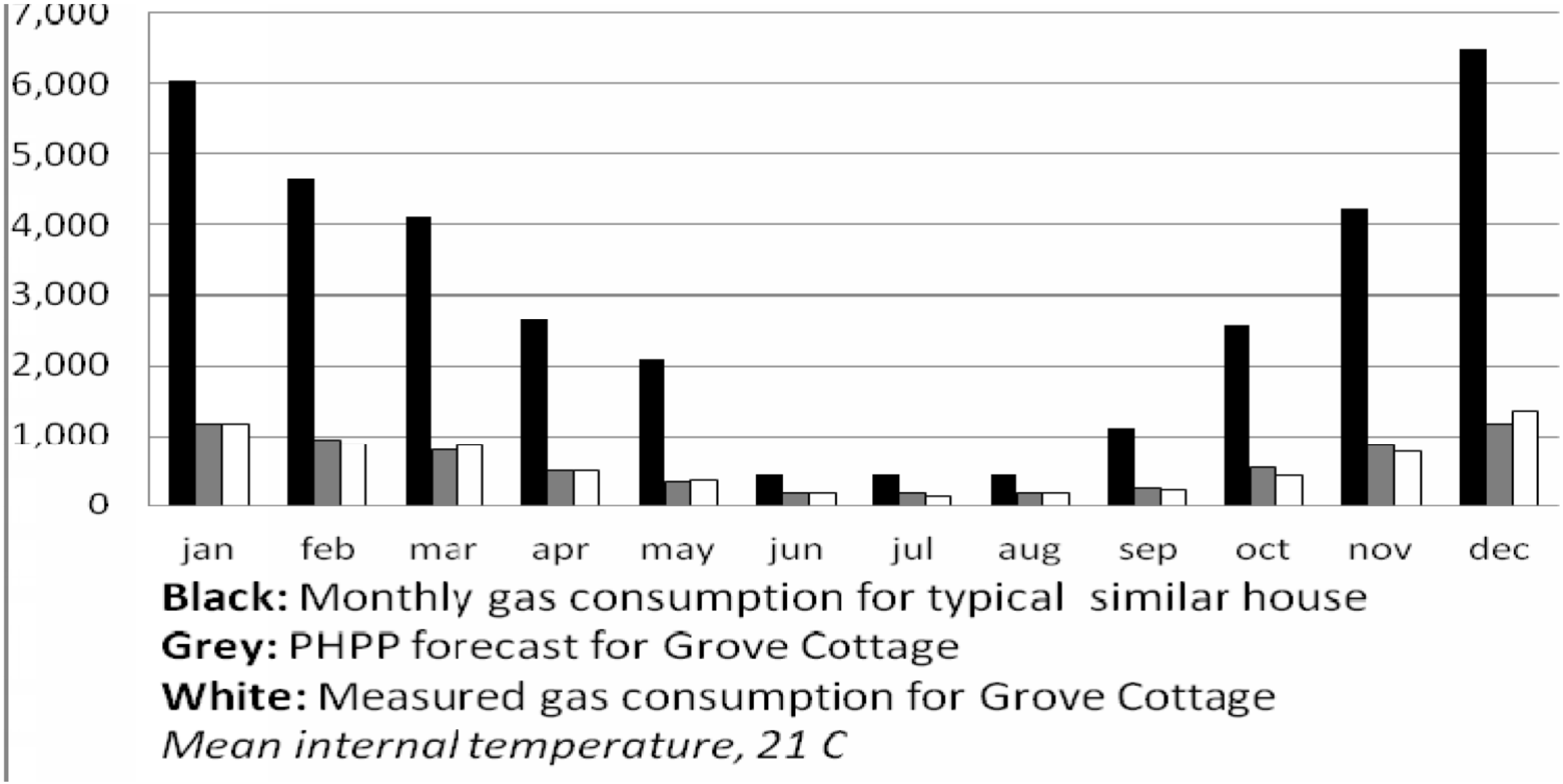
DESIGN - REALITY GAP





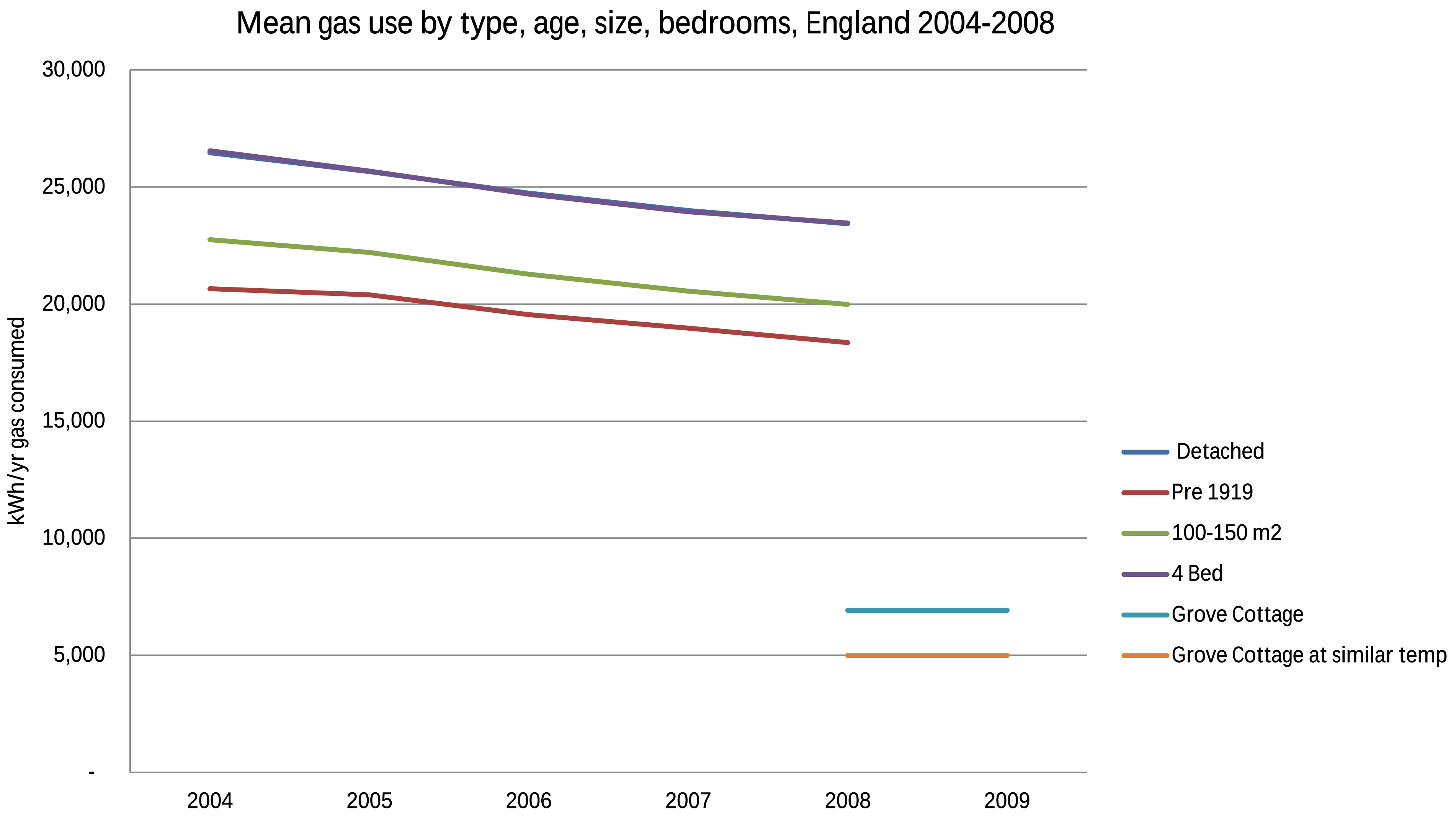
Absolute CO2 reduction: original 90m^2 house = 7 T/year now 135m^2 & 3 T/year

MEASURED: Grove Cottage gas consumption – after retrofit
(cooking, space and water heating during 2010)



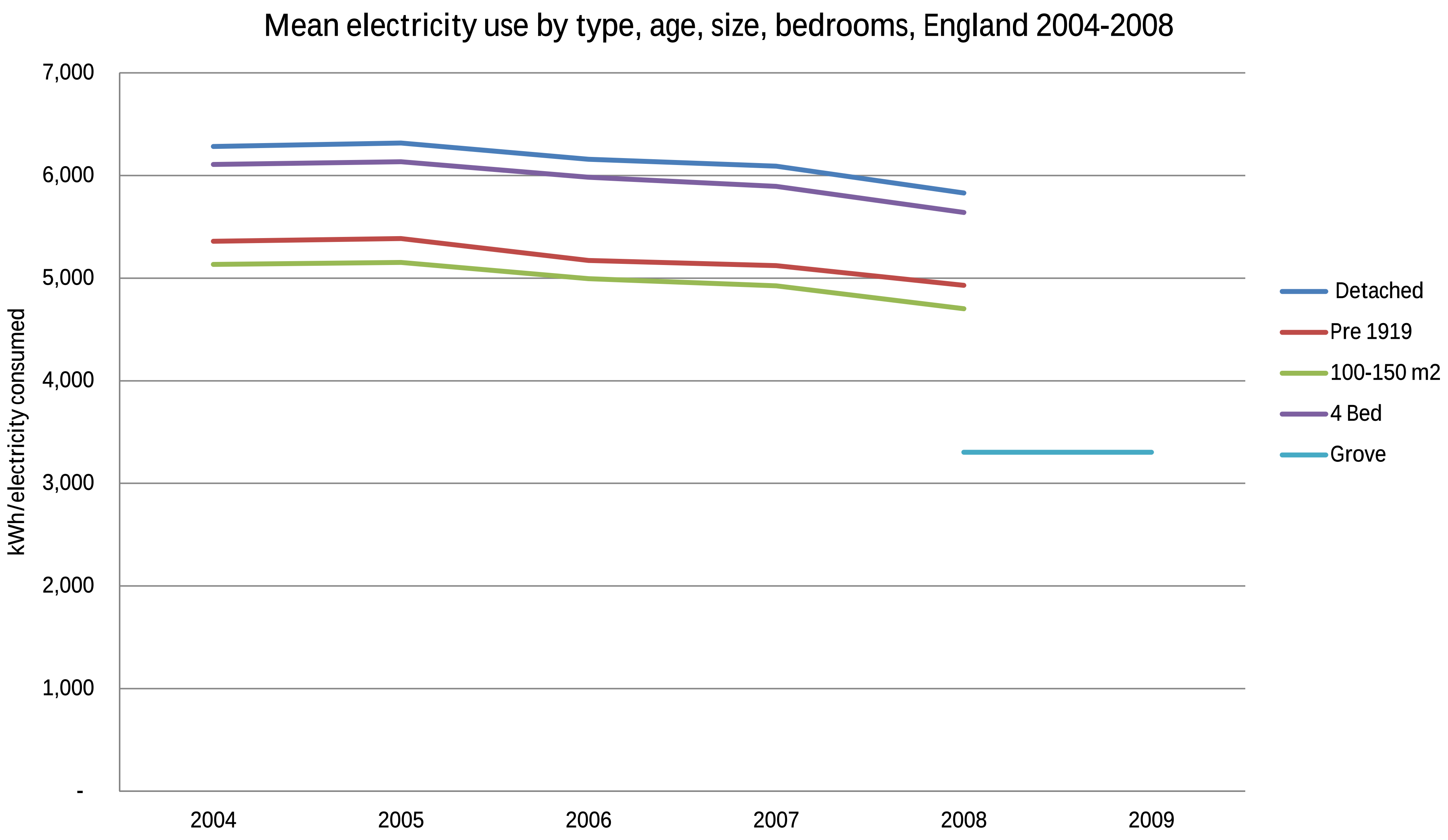
No electric or biomass ‘top up’ heating
No PV or solar thermal panels.

Typical gas consumption - national statistics
Grove Cottage: 70% reduction (used 6,900 kWh/yr)



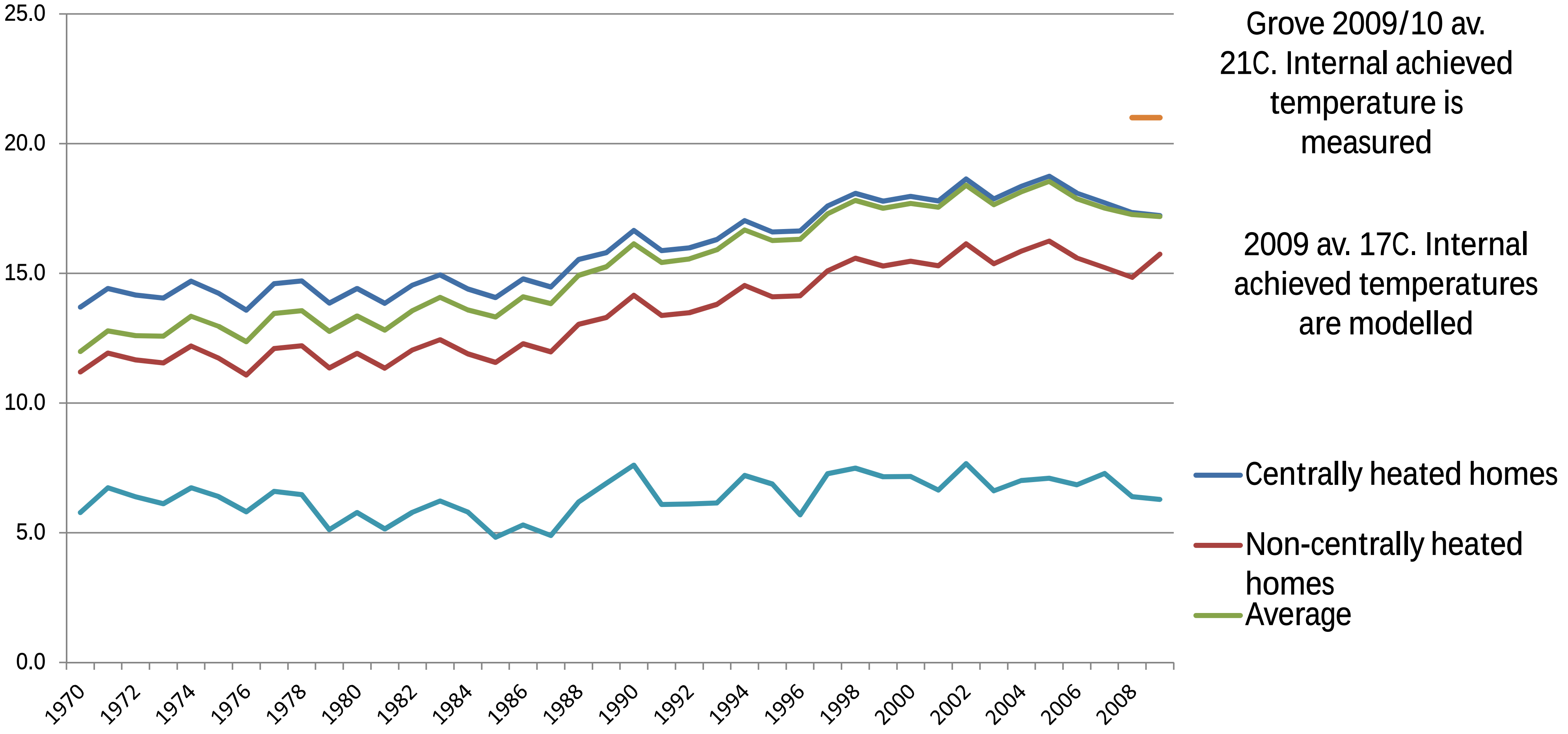
- Graph generated from DECC Publication URN 11D/808

Typical electricity consumption – national statistics
Grove Cottage: 40% reduction (used 3,300 kWh/yr)



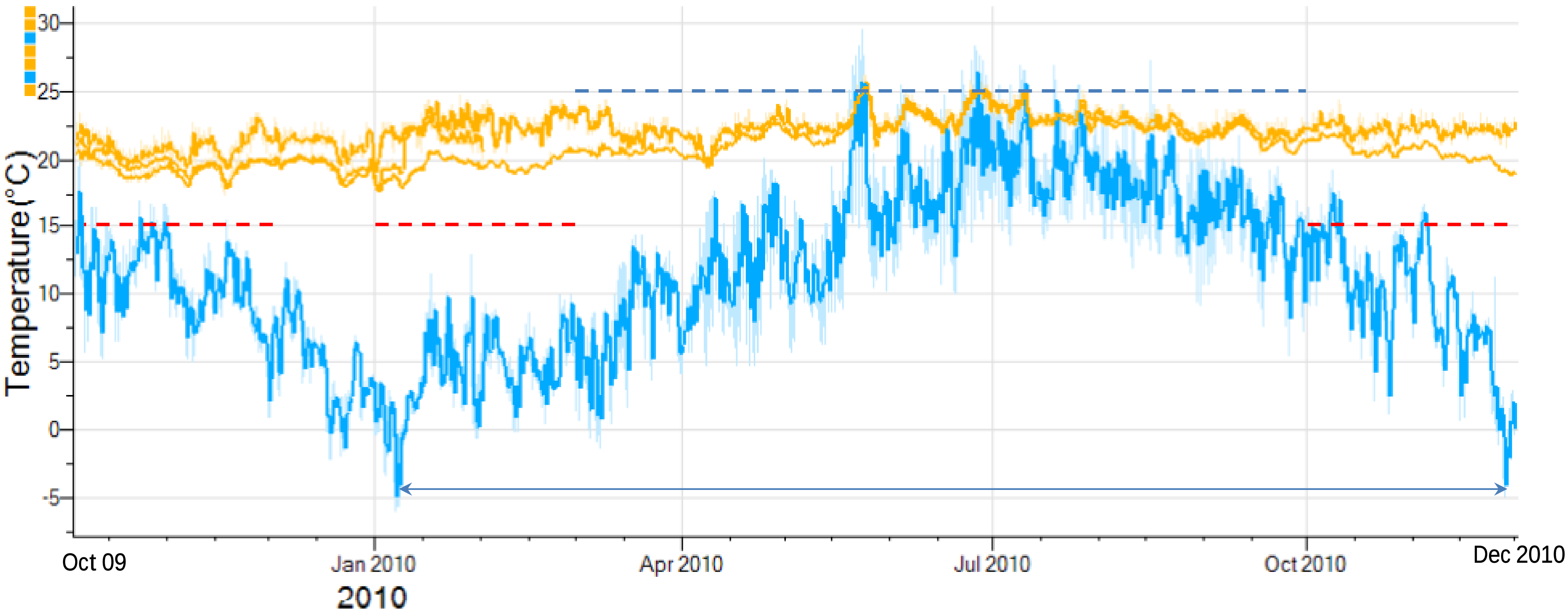
- Graph generated from DECC Publication URN 11D/808

Comfort: internal temperatures
January to March and October to December



- BRE Domestic Energy File, 2003
- BRE, Carbon Emissions Reductions from Energy Efficiency Improvements to the UK Housing Stock, 2001
- Great Britain's Housing Energy Fact File 2011, DECC, URN: 11D/866, page 12
- Graph generated from DECC Publication URN 11D/808

MEASURED: temperatures after retrofit
October ‘09 - December ‘10



Yellow lines
- First floor bedroom
- First floor bathroom
- 'Piano room‘ moved later to ‘Living’

Blue line
- external temperature

MEASURED: temperatures after retrofit
Summary 2010

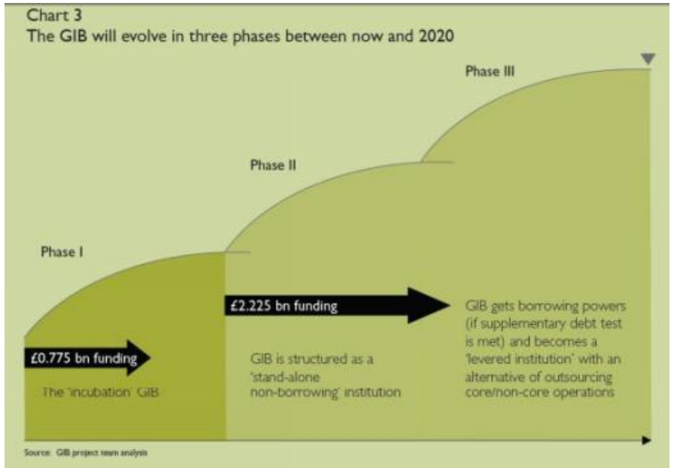
Where	Min	Max	Range	Radiator?	Characteristics worth noting
Outside	-9	28	37		A colder than average winter
Living room	19	22	3	No	uninsulated party wall during period, No radiator, cellar below, west facing window (shading)
Bedroom	18	24	6	No	No radiator, 2 exposed walls, 1st floor west facing window
Bathroom	22	25	3	Yes	Solar gain (due south), boiler cupboard

.

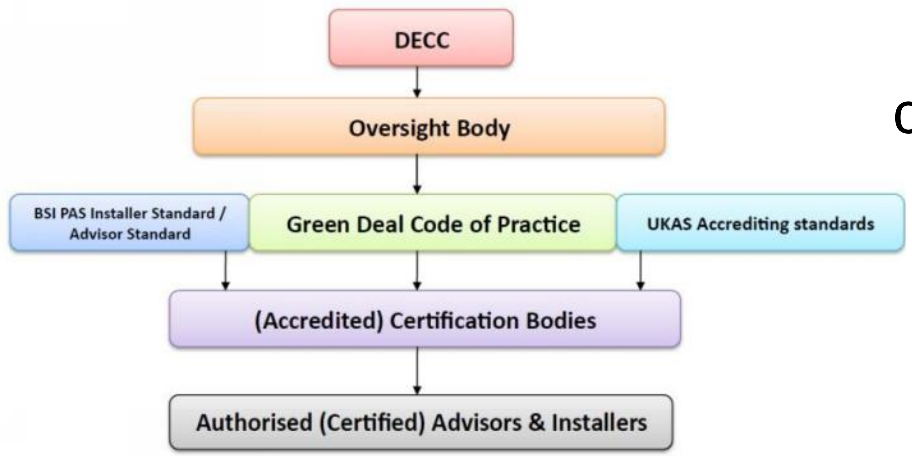
Mean internal measured temperature during heating season

21C

The Green Deal

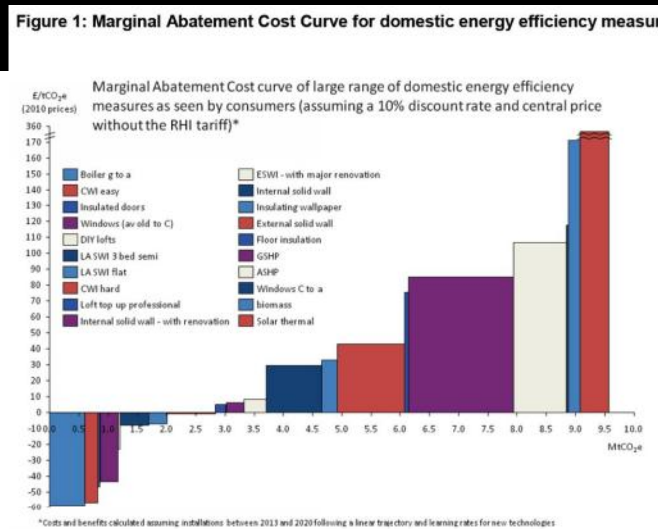


The lender



Chain of command

Delivery

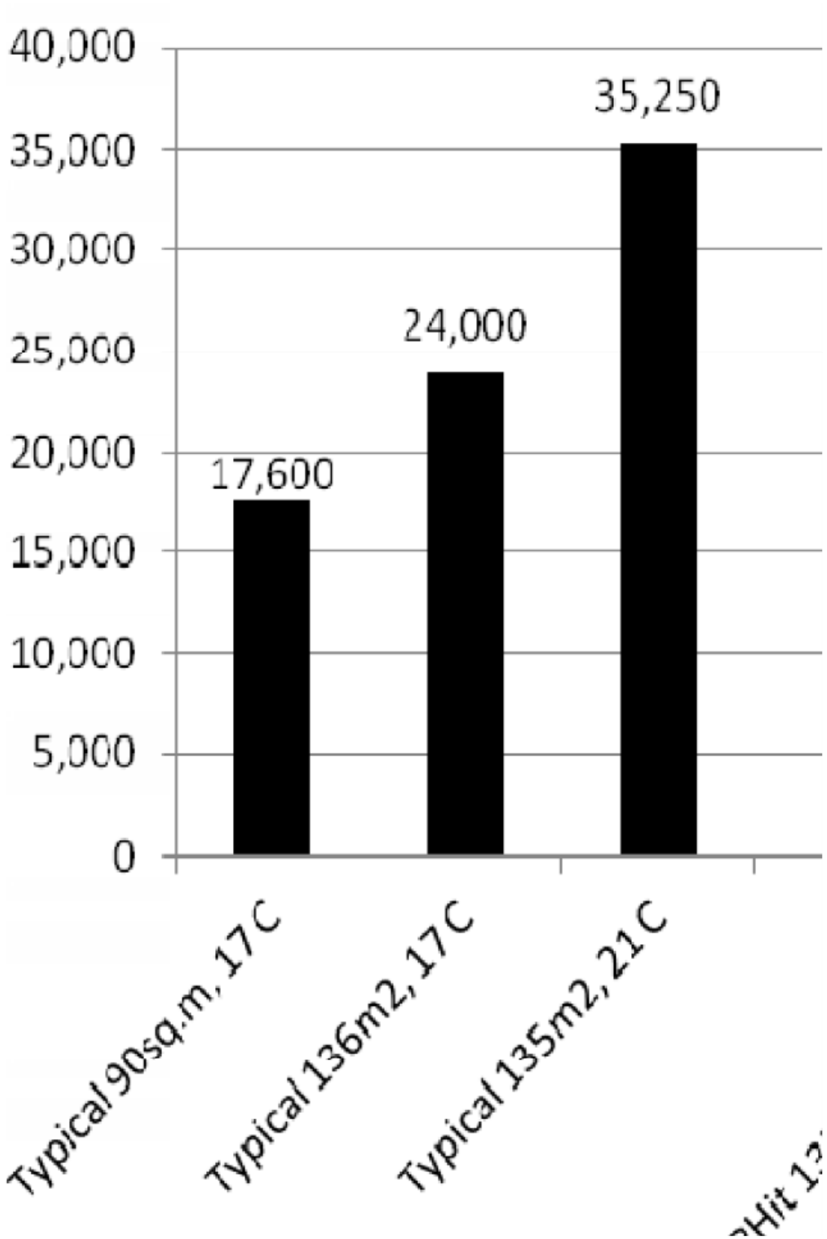


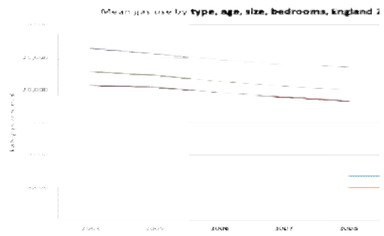
Cost effective measures:
take out a GD loan
Less cost effective measures:
try for ECO or use other funds

Air source heat pumps	High thermal performance external doors
Biomass boilers	Hot water cylinder insulation
Biomass room heater with radiators	Internal wall insulation
Cavity wall insulation	Loft or rafter insulation and loft hatch insulation
Change heating to high efficiency gas-fired condensing boilers	Lighting systems, fittings and controls
Change heating to oil-fired condensing boilers	Mechanical ventilation with heat recovery
Cylinder thermostats	Micro combined heat and power
Draught proofing	Micro wind generation
Energy efficient glazing	Photovoltaics
External wall insulation	Roof insulation
Fan-assisted replacement storage heaters	Room in roof insulation
Flue gas heat recovery devices	Solar water heating
Ground source heat pumps	Under-floor heating [in combination with measures specified in Part 1, Section 3 of the Statutory Instrument (interpretation section)]
Heating controls (for wet central heating system and warm air system)	Under-floor insulation
High efficiency replacement warm-air units	Waste water heat recovery devices attached to showers

Eligible measures
Approved list

Making a 'typical' house 'similar' - using NHER Evaluator



Modelling a 'typical house' and making it 'similar' to Grove Cottage	**Gas (kWh/yr)** 
The 'typical', UK house, 90sq. m @17C. (same occupancy)	17,600
Floor area increased to match Grove Cottage – 135 sq. m @ 17C	24,000
Temperature increased to match Grove Cottage, 135 sq. m @ 21C	35,250

Above figures from John Willoughby, based on figures from BRE Domestic Energy File, 2003

EnerPHit vs Green Deal measures - using PHPP

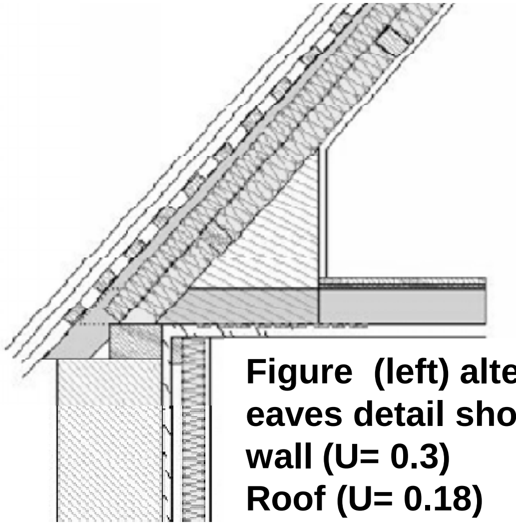


Figure (left) alternative GD eaves detail showing internal wall (U= 0.3) Roof (U= 0.18)

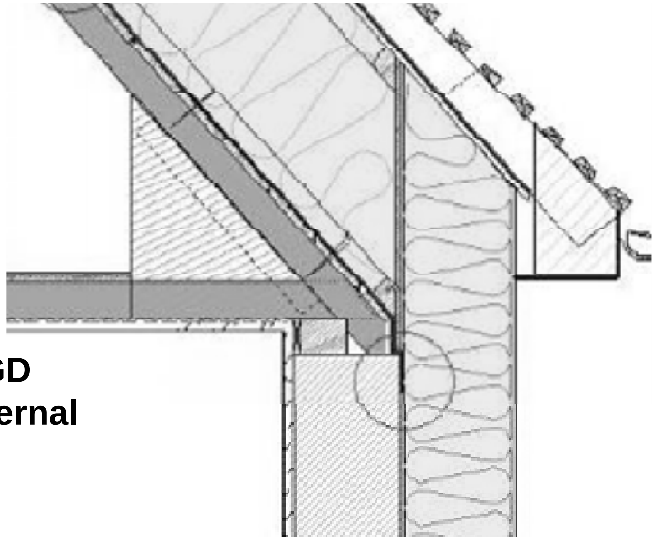


Figure (above right): Eaves detail as built. Roof U = 0.09

Figure (below left) alternative GD external wall to suspended floor (U= 0.25)

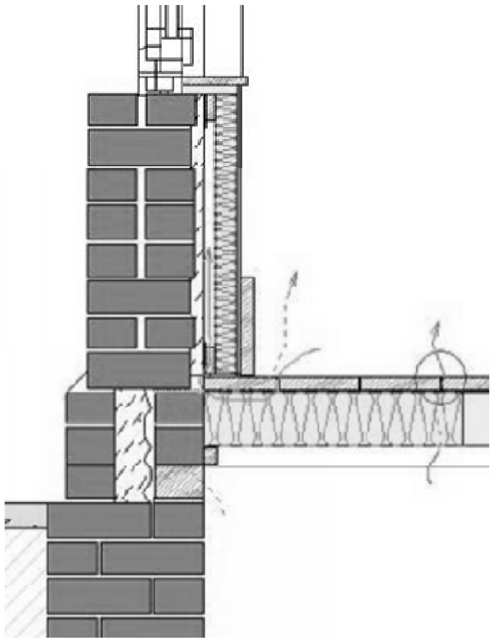
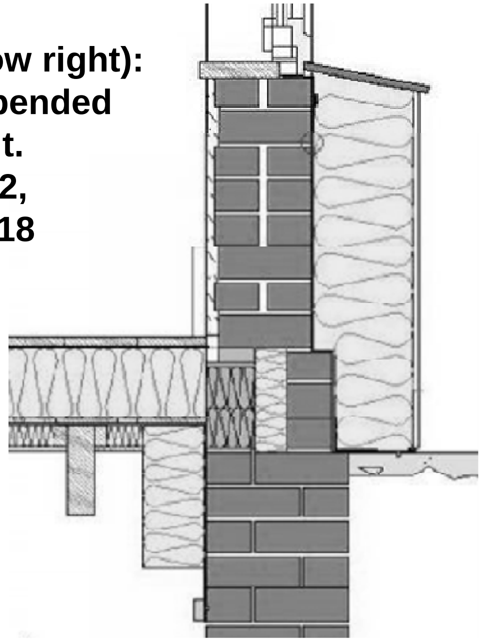


Figure (below right): Wall to suspended floor as built. Wall U = 0.12, Floor U = 0.18

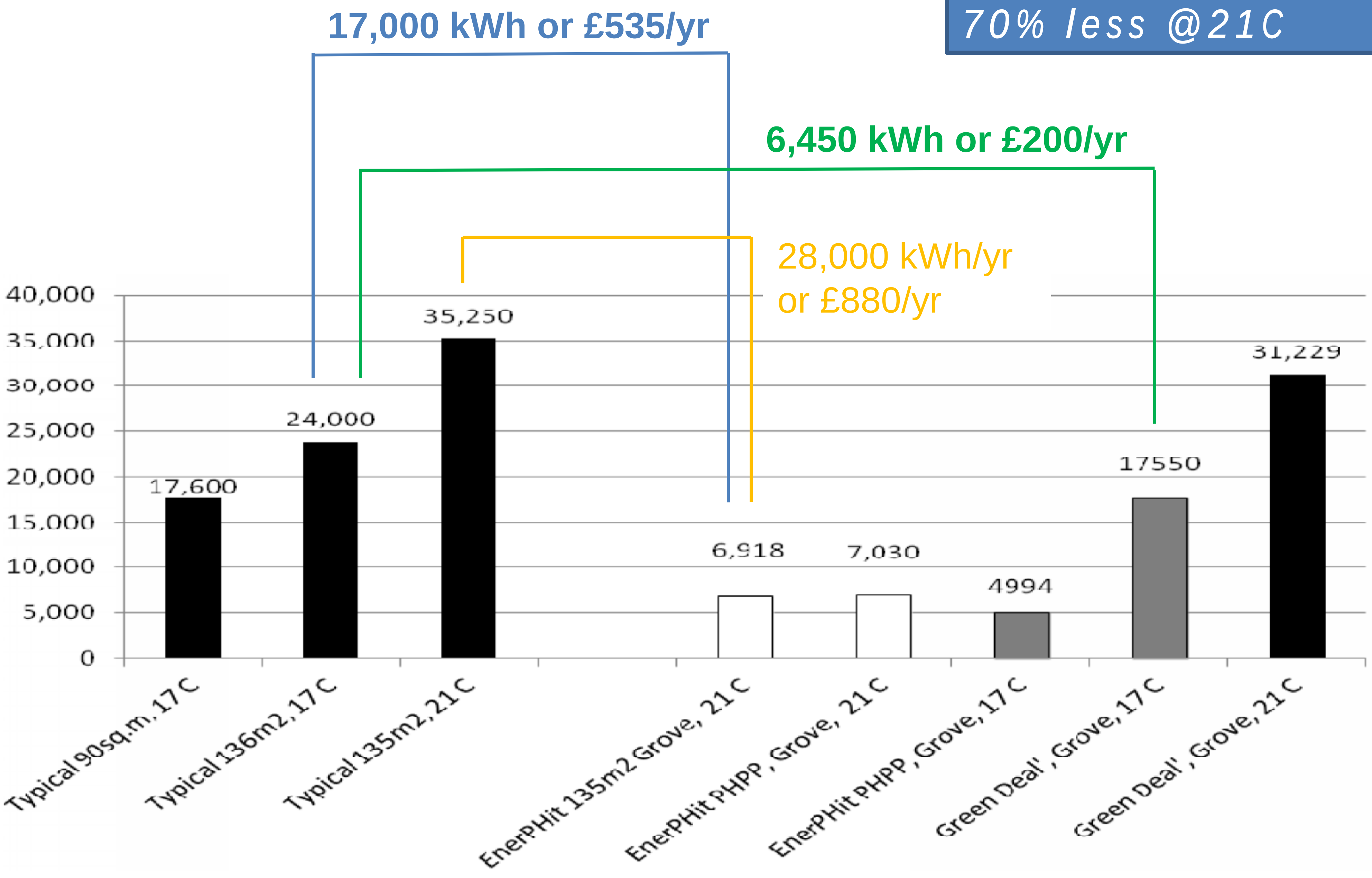


'Likely' GD measures
Double glazed uPVC windows and doors: Air permeability of 5.0 m3/m^{2}h @50 Pa: Whole house mechanical extract ventilation: Insulation levels to current building regulations: Hard to treat solid floor – no improvement.

The construction details illustrated also indicate a view of the difference in the design and specification approach likely under the Green Deal.

Modelling GD measures using PHPP

Grove Cottage:
80% less gas @ 17C
70% less @21C



Conclusions

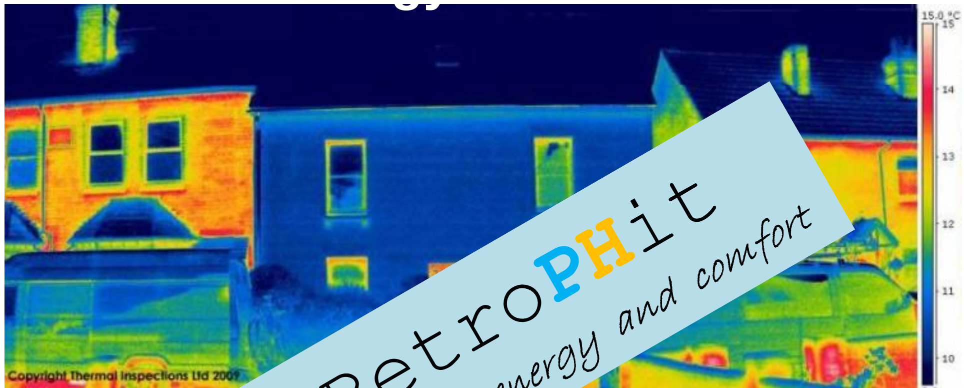
	'Model programme' - informed by the Passivhaus movement			UK Green Deal
A	At a level of ambition consistent with achieving UK climate change targets	√	X	Too constrained by GD financial mechanism - not consistent with climate change targets
B	Clear comfort target accomodated	√	X	No explicit comfort target – probable low internal temp. outcome
C	Explore economic balance between decarbonised heat supply and building measures	→	←	Current scenario: expensive, unlikely 'decarbonised electric heating'
D	Typical measures deliver against 'A' & future proof against fuel poverty	√	X	Pitched at current UK building regulations using sub optimum measures – only *delaying* fuel poverty
E	Well researched measures, good QA + culture of monitoring / feedback	√	X	Inadequate research and guidance, weak QA & monitoring /feedback
F	Generally as 'outsider' has good PR ('Quality/Comfort/low bills')	√	√	High profile: risks entrenching & defending weak programme - not improving it
G	SCALE & COST 625,000 homes/ year = large savings on UK's energy bill, 250, 000 - 500, 000 new jobs created. Annual investment by UK PLC - around £8 billion/yr			GD loan for basic eligible measures @5-6% interest. Additional ECO subsidy for further measures 'a lottery' - distribution by energy companies
	Offers a way forward			A dangerous distraction

Conclusions

A range of robust standards for UK retrofit			
Reductions in Primary Energy	UK average = 409 kWh/m2.a		
	Measures attached to buildings - 80%		Measures attached to buildings - 40%
	No decarbonised heat supply		Decarbonised heat supply - 40%
Certifiable standard	PH	EnerPHit	[RetroPHit ‘low energy’], EnerPHit $^{+i}$
Typical application	Rural, no low carbon heat supply available, where easy opportunity		Urban/low carbon heat supply available

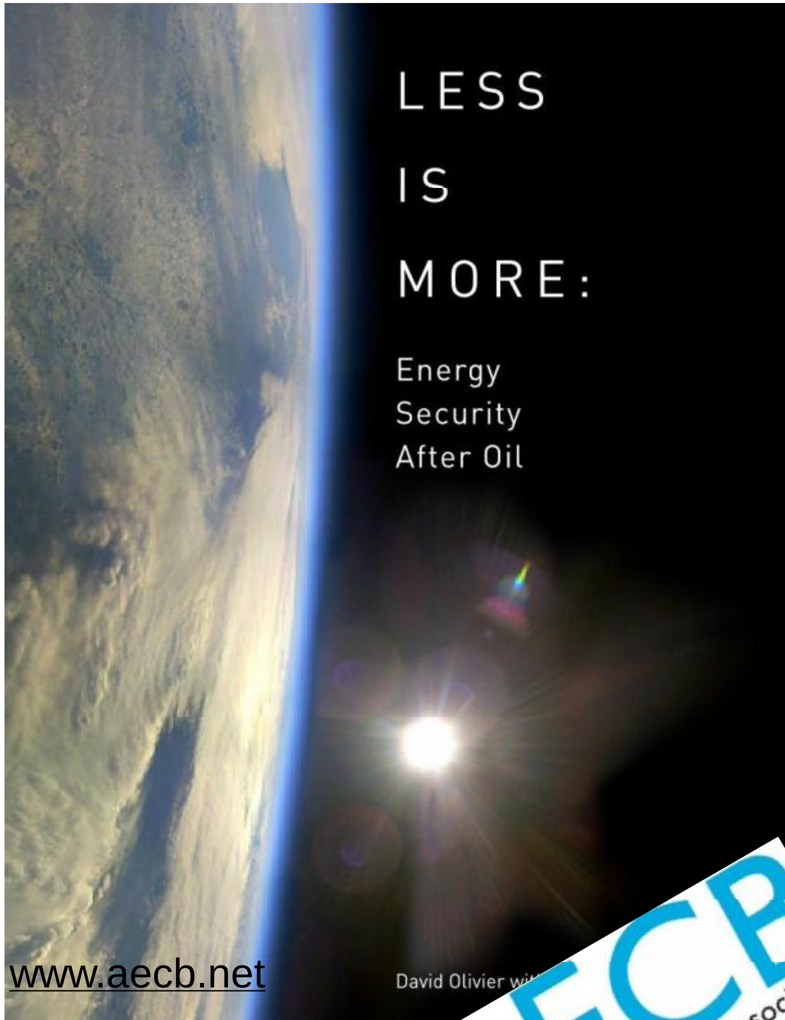
Passivhaus - new

Simmonds Mills
ARCHITECTS
ECOLOGICAL DESIGN
SUSTAINABLE CONSTRUCTION
www.simmondsmills.com



RetroPHit
affordable energy and comfort

Passivhaus Trust
The UK Passive House Organisation



www.aecb.net

AECB
the sustainable building association

UK EnerPHit case study: what lessons for the UK Green Deal Programme?

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andy@simmondsmills.com

1. Introduction

"...The rebound theory certainly makes it clear that behavioural and societal norms are proving to be a barrier to creating sustainable housing. The WBSCD[1] has identified barriers to individuals becoming energy efficient as:

• the desire to be comfortable..."[2]

Figure 1: Grove Cottage (left) after refurbishment

Grove Cottage - an existing 1869 solid brick house – refurbished in 2008/09 to the EnerPHit standard provides post construction measured energy consumption, internal and external measured temperatures. Using data from 2010 this paper attempts to set the EnerPHit standard in a UK context for houses of this type: owner occupied, detached/semi-detached, built pre-1919 solid walled housing stock using natural gas. Gas consumption for space heating, water heating and cooking is first compared to the consumption of a similar typical 'unimproved' house and secondly compared to a ‚non-EnerPHit' Grove Cottage - modelled in PHPP with retrofit measures typically proposed under the the UK Government's new Green Deal energy efficiency programme. The paper attempts to illustrate and compare potential levels of energy saving resulting from both the EnerPHit and Green Deal approach. It touches on the current confused debate around future housing energy demand, the level of fuel bills, current and future comfort levels and the perceived cost effectiveness or otherwise of the various energy effciency measures as applied to buildings.

There is no clear strategy in the UK concerning acceptable target temperatures for UK homes. This issue makes the task of assessing the role of the EnerPHit refurbishment standard, with its resultant reduced energy consumption *and* increased comfort level, very difficult in the UK context.

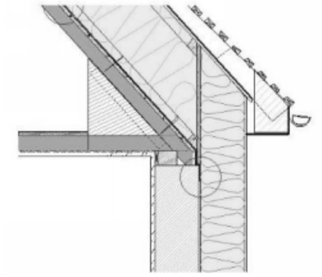
[1] "The WBCSD [will] act as the representative of progressive business [at Rio+20], highlighting the advances it has made towards sustainability. By engaging with key stakeholders the WBCSD will explore the roles and responsibilities of business and others in moving towards a sustainable world." [http://www.wbcsd.org/home.aspx]

[2] Extract form quote: http://nhbcfoundation.blogspot.com/2011/10/phenomenon-of-rebound-effect-is.html.

2. Grove Cottage – Passivhaus or EnerPHit?

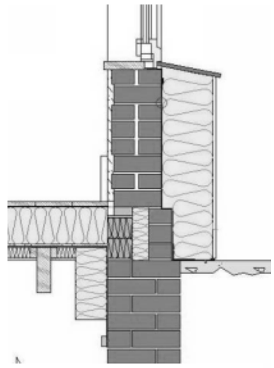
In 2008 the author - drawing on previous experience of designing and constructing low energy buildings and the extension and refurbishment of historic buildings - set out to refurbish his 90m^2 solid brick walled Victorian family home in the City of Hereford, England and to extend it by a further 45 m^2.

Figure 2: Eaves detail as built. Roof U = 0.09



The design team was tasked with achieving a level of performance as close as practical to the Passivhaus Standard. Planning permission for the extension and the retrofitting measures was approved *before* the project was modelled using PHPP.

Figure 3: Wall to suspended floor as built. Wall U = 0.12, Floor U = 0.18



The design and specification at this early stage followed AECB CarbonLite guidance[3] and was based on general principles of energy efficiency and passive solar design. PHPP was used prior to a Building Regulations application to refine the thermal envelope, fenestration, ventilation design and heating system. A partially complete PHPP model indicated that a space heat demand of around 18 – 21 kWh/m2.a should be possible, based on a temperature of 20 C. The team cautiously decided to retain the existing radiator system with no space heating load delivered via the ventilation system.

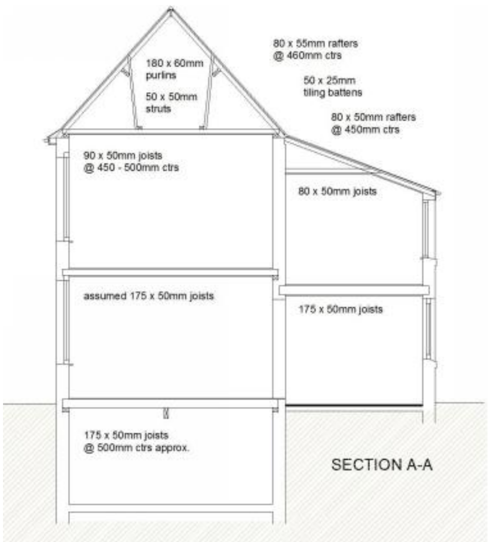
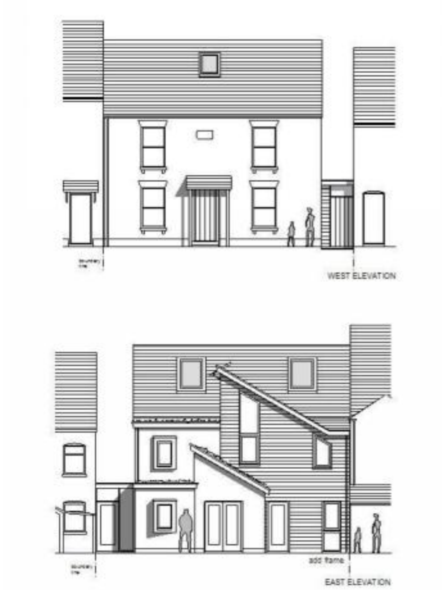


Figure 4: Section through original house (left) & elevations as proposed (right)



3. Construction

The construction work was carried out by a team of builders led by Mike Neate of ECO-DC and a specialist external wall insulation installer. The work was completed, over a period of 9 months, in March 2009. The contractual arrangement was based on agreed day rates and the work managed jointly by the builder and the Architect. The house was awarded certification by the PHI in 2011 - becoming the first certified domestic EnerPHit in the UK.

[3] http://www.carbonlite.org.uk/carbonlite/downloads.php

Figure 3 (from left clockwise): Timber I beams over old roof: attention to airtightness detail at boundary: MVHR duct run: making windows airtight to wall: turf roofs to rear: wall insulation: variable vapour air barrier to basement ceiling..

4. Measured performance

Fuel use has been recorded from April 2009 along with internal and external temperatures and relative humidity. This paper is based on data collected Jan – Dec 2010. Three room temperatures were recorded: first floor bathroom, first floor bedroom & ground floor living room - only the bathroom has a conventional heat source (a small radiator), the bedroom and the living room have no radiators. The occupants appreciate the total lack of cold draughts during the winter months, lack of overheating in summer and consider the internal air quality to be excellent.

Max / min external temperatures measured - Winter / Summer Max temperature 28C / Min temperature -9C		
Max / min room temperatures - Winter / Summer		
Bathroom	**Bedroom**	**Living Room**
max 24.57 / min 21.75C	Max 24.40 / min 18.46C	max 22.40 / min 19.23C

Table 1: 2010 recorded internal temperatures. Note the average house temperature during heating season was 21CThe paper focuses on the consumption of mains natural gas used for space and water heating and cooking. No electric or biomass ‘top up’ heating is used in Grove Cottage but some of the electricity consumption measured was used to heat a separate home office in the garden. Total consumption for 2010 was (electricity) 3,300 kWh and (gas) 6,918 kWh.

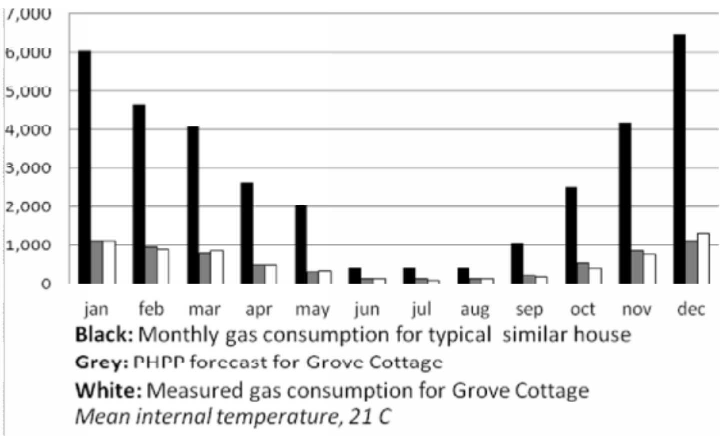


Figure 4 Measured and forecast monthly gas consumption 2010 compared to ‚typical‘

4. Basis of comparison with ‘typical’ and ‘Green Deal’ houses

Internal temperatures – assumptions

Between 1970 and 2001 there was an average 6C rise in indoor temperature[4]. The 2001 winter average is reported as 18.89C. By 2020 the average internal temp is expected to be not far from 19.25C[5]. The English House Condition Survey (1991) recorded spot temps of 18.6C and 16.6C. The values from 1996 were 18.1C and 16.8C. 24 hour averages would of course be slightly lower than these quoted figures.

Modelling Grove Cottage - EnerPHit

The project PHPP file was used, with the internal temperature adjusted to 21C and 17C and with the monthly mean temperatures changed using the UK Met Office official 2010 figures for the Midland region**.**

Modelling Grove Cottage – Green Deal + ECO

The size and form of Grove Cottage and its new extension is reasonably representative of this type of house in the building stock i.e. an original smaller house with a rear extension. The measures were removed from the PHPP model in order to take the whole house back to an 'unimproved state'. A number of measures suggested by the Green Deal programme were applied. The internal temperature was then set in PHPP to match that of the original 'unimproved' house (17C) and then to a higher temperature to match Grove Cottage (21C).

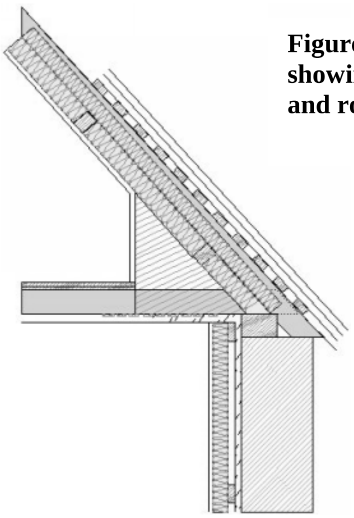


Figure 5 (left) Grove Cottage eaves detail showing internal wall insulation (U=0.3) and roof insulation (U=0.18)

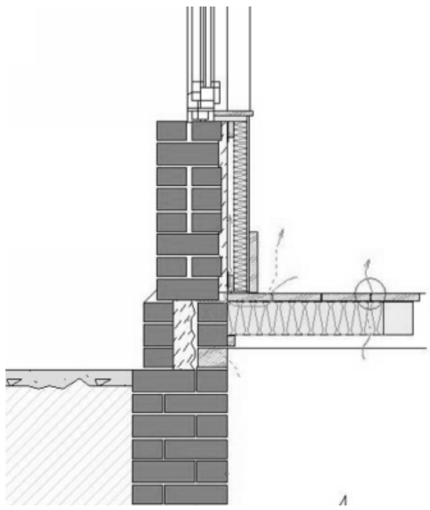


Figure 6 (right) external wall to suspended floor (U=0.25)

Typical measures: retention of existing double glazed uPVC windows and doors throughout, air permeability of 5.0 m3/m^{2}h @50 Pa, whole house mechanical extract ventilation, insulation levels to follow current building regulations and for the hard to treat solid floor – no improvement. The construction details illustrated also indicate the author's view of the difference in the design and specification approach likely under the Green Deal.

Modelling a 'typical' UK house

Approximately 40 % of houses in England are either detached or semi-detached, and approx. 15% are detached[6]. Grove cottage is technically detached but has some characteristics of semi-detached given the proximity of the neighbouring property. The 'typical' house modelled in this paper is based on a semi-detached house type (typically

[4] BRE Domestic Energy File, 2003
[5] BRE, Carbon Emissions Reductions from Energy Efficiency Improvements to the UK Housing Stock, 2001
[6] Great Britain's Housing Energy Fact File 2011, DECC, URN: 11D/866, page 12

consuming less than a detached) - the national statistics quoted for detached houses in Table 2 are used as a cross check. It is also worth noting, with respect to these gas consumption statistics that no account is made of any electricity used for 'top up' heating of colder rooms via individual electric room heaters. Another reason for the 'typical house' model potentially underestimating space heating consumption arises from the characteristics of the [7]modelling software used (NHER Evaluator) – these figures were produced as part of a separate earlier modelling exercise and have been reused here. The PHPP modelling has been carried out specifically for this paper. These factors no doubt distort the comparison exercise to some degree. Evaluator was used with data from the [8] BRE Domestic Energy Factfile 2006 adjusted for 2010 degree days based on measured average fuel consumption figures and average temperature (17.8 degrees). An average sized house was modelled with insulation levels, air permeability and heating efficiency that result in this average fuel consumption, the fabric areas were increased to give a floor area of 135 m2 (as Grove Cottage) and then demand temperature was increased until the whole house mean internal temperature = 21C . Gas consumption figures from this, for space and water heating and cooking, were then used to produce Fig. 7 below.

How 'typical' is Grove Cottage in England? Some UK consumption statistics[5]	**GAS (kWh/yr)**	**ELECTRICITY (kWh/yr)**
By house type (detached)	21,470	4,600
By property size (100-150m2 floor area)	18,500	4,000
By property age (pre- 1919)	16,500	3,550
By tenure (owner occupier)	17,500	3,700
By number of bedrooms (4)	21,500	4,750
Average of the above	19,094	N/A
Cross check: *detached* house, quartiles , west Midlands	11,000 - 21,500	N/A
The 'Typical', UK house modelled in this paper, 90sq. m, 17C	17,600	
Floor area increased to match Grove Cottage – 135 sq. m, 17C	24,000	
Temperature increased to match Grove Cottage, 135 sq. m, 21C	35,250	

Table 2

5. Conclusion

Comparing the EnerPHit refurbishment with a typical similar unimproved house, both at 21C gives a saving on gas consumption of 28,000 kWh/yr or £880/yr. However for a typical house an internal mean temperature of 21C is unlikely to be afforded, so the savings are better expressed relative to a typical house at a mean internal temperature of 17C i.e. 17,000 kWh/yr or £535. In reality it seems unlikely that a typical house using 24,000 kWh/yr would actually reach the mean internal temperature of 17C predicted by the NHER software.

Generally mean internal temperatures during winter are probably lower in UK homes than officially recognised - this typical house may in reality have a mean temperature of around 15-16C – or use secondary non-gas heating e.g. electric heaters or woodstove(s) to achieve comfort conditions.

[7] Projecting energy use and CO2 emissions from low energy buildings - A Comparison of PHPP with SAP. http://www.aecb.net/PDFs/Combined_PHPP_SAP_FINAL.pdf
[8] http://projects.bre.co.uk/factfile/TenureFactFile2006.pdf

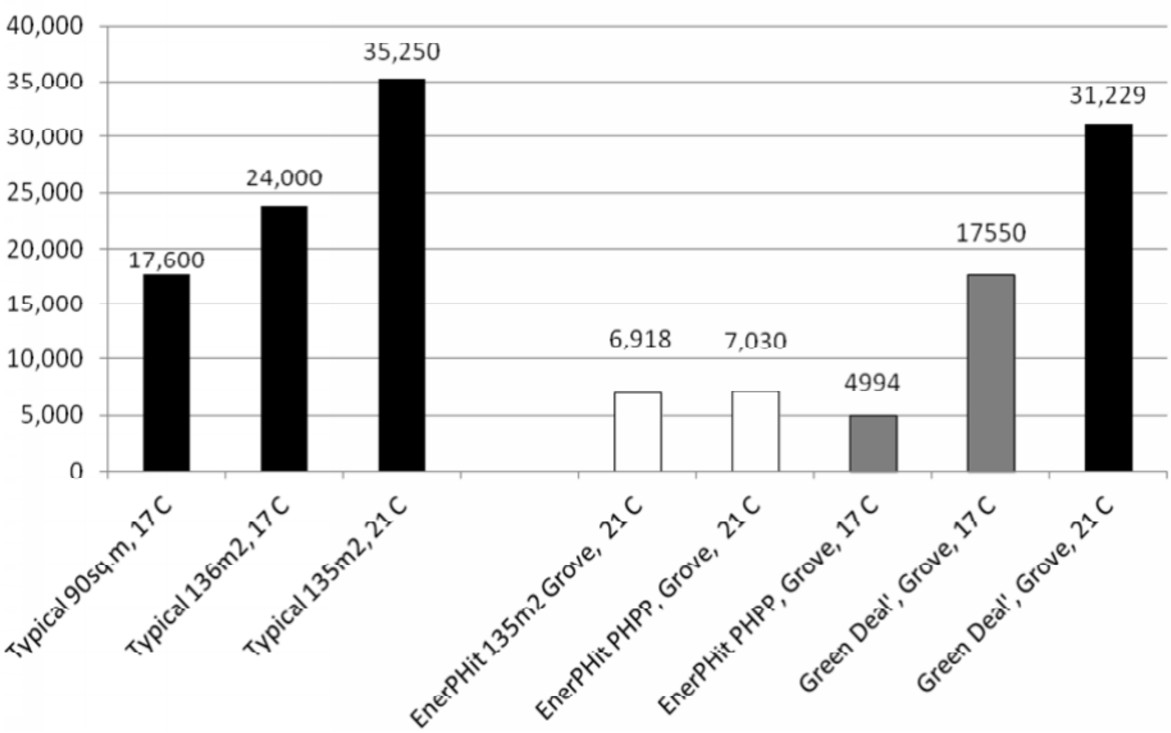


Figure 7 Gas consumption

The PHPPP model of Grove Cottage with only Green Deal type measures applied suggests savings of 6,450 kWh/yr or approximately £200/yr compared to the typical unimproved house. If these savings were taken in increased comfort – heating the house to a slightly higher mean temperature - then no reduction in energy use would result. To achieve a mean internal temperature of 21C following the Green Deal measures would incur much higher energy consumption and increased energy bills compared to the unimproved house – modelled here at over 31,000kWh/yr.

In conclusion the author feels that Enerphit offers a *reliable* route to achieve dramatic savings on fuel bills *with increased comfort*. EnerPhit measures are likely to be economic at current fuel prices for low density rural buildings of this type, off the gas grid and away from sources of waste or other low carbon heat and/or district heating opportunities. The Green Deal programme seems unlikely to be perceived as an attractive financial incentive to householders, despite offering commercial and marketing opportunities for companies selling products and services. Furthermore, taking into account expectations of increased comfort following refurbishment measures, it also seems unlikely that the programme will deliver energy savings in houses of this type – it may deliver some small increases in mean internal temperatures. Green Deal refurbishment appears to promote inadequate retrofit measures if householders wish to be able to live affordably at comfortable internal temperatures.