Part L 2013

Preliminary Modelling Results

New Homes

As carried out: March/April 2011

NOTE

This is a working report produced to inform discussions and help elicit views from the Industry Working Group tasked with considering domestic standards for Part L 2013.

The modelling work described is preliminary modelling only and has since been superseded by more detailed modelling for the Part L 2013 consultation documents and impact assessment by Aecom and the Zero Carbon Hub under contract to DCLG.

This report does not represent firm Government policy which is subject to further development, formal consultation and ministerial decisions.

Contents

Introduction

The Zero Carbon Hub were asked by DCLG to extend the dwelling modelling work undertaken for the Carbon Compliance Task Group[1] such that it covered the spectrum of current (2010) regulations to the recommended Carbon Compliance limits for 2016. This would include both the technical feasibility and commercial issues (capital and lifecycle costs).

The outputs would cover the core dwelling types and fabric specifications used for the Carbon Compliance work. Additional modelling work would also be carried out for a third fabric energy efficiency specification. Ten heat technology scenarios were selected, utilising the same efficiency assumptions as the Carbon Compliance work.

The 2013 Part L standards for dwellings need to be pitched at a level which gives the development industry a clear trajectory to the proposed 2016 standards. It is intended for this initial modelling work to act as an indication of the implications of potential decisions and a starting point for further discussions/ more detailed and specific modelling work.

The challenge for 2013 Part L1A

Much of the work undertaken by the Zero Carbon Hub regarding the 2016 standards for zero carbon homes recommends changes to the current Part L methodology and therefore should form part of the considerations for the 2013 standards. The main areas for consideration pertain to:

- Percentage reduction vs. absolute carbon limits
- Flat vs. aggregate emission targets
- Design vs. as-built performance
- Methodology for determining CO_2 emission factors
- Use of fuel factors
- Use of weather data
- Review of and updates to SAP
- Reporting of primary energy limit

Information on these areas in relation to zero carbon homes can be found in the following Zero Carbon Hub reports:

- Carbon Compliance for Tomorrow's New Homes[2]
- Carbon Compliance – Setting an appropriate limit for zero carbon new homes[3]

[1] See http://www.zerocarbonhub.org/definition.aspx?page=8 for details of the Carbon Compliance Task Group recommendations and an overview of the modelling work carried out. The final report can be accessed directly here: http://www.zerocarbonhub.org/resourcefiles/CC_TG_Report_Feb_2011.pdf

[2] http://www.zerocarbonhub.org/resourcefiles/CARBON_COMPLIANCE_GREEN_OVERVIEW_18Aug.pdf and associated Topic reports: http://www.zerocarbonhub.org/definition.aspx?page=8

[3] http://www.zerocarbonhub.org/resourcefiles/CC_TG_Report_Feb_2011.pdf

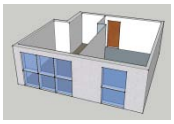
Technical issues

Overview of methodology

The modelling uses the same modified version of SAP2009, provided by National Energy Services (NES), used for the Carbon Compliance modelling work[4] . Fuel Factors[5] have not been used. A location of East Pennines was used throughout.

Dwelling types

Five standard house types were modelled (Figure 1). These are the same core dwelling models used by the Zero Carbon Hub for both the Fabric Energy Efficiency and Carbon Compliance work previously carried out for Government.

	Small Apartment	Large Apartment	Mid Terrace House	End Terrace / Semi Detached House	Detached House
	 Top floor Mid floor Ground floor	 Top floor Mid floor Ground floor			
TFA (m²)	43	66	76	76	118

Apartment blocks
3, 4, 8 & 20 storey
(4x small & 4x large per floor)

Figure 1: *Dwelling types modelled*

Fabric specifications

All dwellings were modelled to three different fabric specifications:

- 'Interim FEE' – An example interim fabric energy efficiency specification (43/52)
- 'FEES' – The Fabric Energy Efficiency Standard for zero carbon homes (39/46)
- 'Spec C' – An example higher fabric specification, approaching PassivHaus requirements

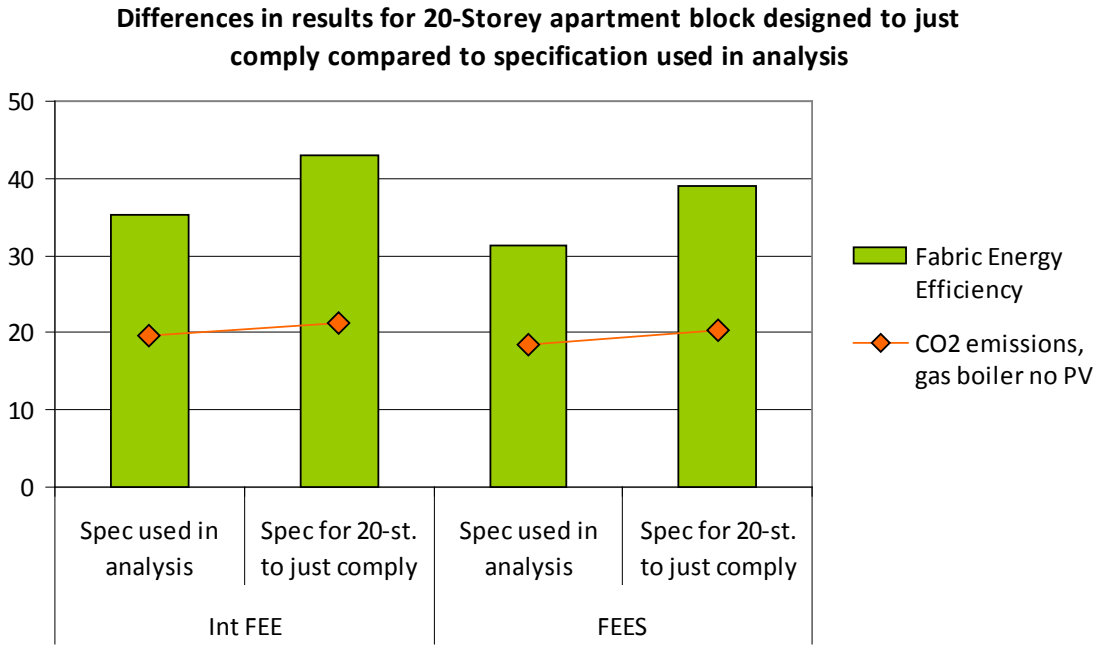
The details of the specifications used can be found in Appendix B1.

It should be noted that for ease the fabric specification for the apartment blocks used in the analysis is the same regardless of how many storeys they are. The worst-case block height has been used to determine the specification used. For the Interim FEE and FEES this is the 3-Storey block. Therefore for higher storey blocks the analysis will be showing lower carbon emissions than might be the case if the specification for those blocks were individually designed to meet the Interim FEE and FEES levels.

[4] This is a modified version of the 'SAP 2009 Preview' software. The modifications allow use of 2016 carbon emission factors and regional weather (temperature, solar radiation, solar irradiation, wind speed) which were required for the Carbon Compliance work.

[5] In current (2010) compliance methodology, Fuel Factors are applied to the calculation of Target CO_2 Emission Rate (TER) depending on the fuel used to provide heat to the dwelling. The effect of this is that, for example, electrically heated dwellings are allowed to emit more CO_2 than an equivalent gas heated dwelling.

This impact of this has been investigated for the 20-storey block and is illustrated in Figure 2 below.



	20-Storey Apartment block			
	Int FEE		FEES	
	Spec used in analysis	Spec for 20-st. to just comply	Spec used in analysis	Spec for 20-st. to just comply
Fabric Energy Efficiency	35.36	42.98	31.21	38.92
CO2 emissions, gas boiler no PV	19.54	21.37	18.55	20.40

Figure 2: *Impact of keeping apartment block specifications the same in the analysis*

Heat technologies

All dwelling and fabric specification combinations were modelled with the following heat delivery technologies:

Individual

Gas boiler

Gas boiler + Solar Hot Water (SHW) [except high-rise apartments]

Direct electric

ASHP

ASHP + SHW [except high-rise apartments]

GSHP [Houses only]

Shared/ Communal

Gas CHP + gas boiler

Gas CHP + biomass boiler

Biomass CHP + gas boiler

Biomass boiler

The efficiency of each technology used in this work is the same as assumed in the Carbon Compliance work where the general principal had been taken that good practice in 2010 would likely equate to standard practice in 2016. A full list of efficiency and other modelling assumptions can be found in Appendix B2.

Carbon emission factors

Three carbon emission factors scenarios have been modelled:

- 'CC4TNH 2016' – The 2016 values used in the Carbon Compliance work[6]
- 'CC4TNH 2013' – 2013 values derived using the same methodology as the above 2016 values
- 'DECC 2013' – DECC marginal grid emissions factor for 2013, with SAP2009 gas emissions factor

A list of the emission factors used is shown in the table below.

Case description >	**CC4TNH 2013**	**CC4TNH 2016**	**DECC 2013**
Fuel	($kgCO_{2(eq)}$/kWh)	($kgCO_{2(eq)}$/kWh)	($kgCO_{2(eq)}$/kWh)
Grid electricity	0.642	0.527	0.3939
Electricity generated on-site	0.642	0.527	0.3939
Mains gas	0.227	0.227	0.198
Biomass community heating	0.019	0.019	0.019
Origin of figures	CC4TNH report methodology[7], values @ 2013[8]	CC4TNH report methodology[7], values @ 2016[8]	Elec: DECC 2013 grid average; Gas: SAP2009; Biomass: as other cases

It should be noted that the intention is that the 2016 Carbon Compliance standard would be re-based if changes occurred to the assumed CO_2 emissions factors used in that work (plus other factors). This has not been taken account of in the modelling carried out for the CC4TNH 2013 scenario or the DECC 2013 scenario. The modelling remains correct, but the absolute level at which Carbon Compliance for 2016 would be deemed to be would change (to a higher level for CC4TNH 2013, and to a lower level for DECC2013 scenarios).

Achievement of particular CO_2 emission limits / CO_2 emission reductions

Each of the heat technology scenarios will lead to the achievement of a particular level of CO_2 emissions / CO_2 emissions reduction. An assumption of the modelling work is that reducing emissions beyond this level is achieved by the on-site generation of zero carbon electricity. The mainstream technology currently usable for a wide variety of individual dwelling types and locations is photovoltaic (PV) panels. Therefore this is what the modelling has assumed.

The Carbon Compliance Task Group agreed that technical feasibility should be assessed by reference to the amount of PV required, taking this as a proxy for all LZC electricity generation technologies. If the area of roof-mounted solar technologies required exceeds a certain proportion of ground floor area, it indicates that specific "solar design" features such as orientation or roof type and pitch may also be required, and other features such as dormer windows or vernacular design may become impractical. This was contrary to the Task Group's general view that the 2016 Carbon Compliance

[6] The 2016 carbon emission factors used in the Carbon Compliance modelling have been derived from best available information, at August 2010, following the methodology recommended in the Zero Carbon Hub's report *Carbon Compliance for Tomorrow's New Homes* (July 2010). This methodology differs from that used for 2010 Building Regulations: it is based on a 15-year forward-looking average of marginal emissions, including upstream emissions and the equivalent effect of other greenhouse gases produced.

[7] Zero Carbon Hub, *Carbon Compliance for Tomorrow's New Homes*, July 2010, http://www.zerocarbonhub.org/definition.aspx?page=8

[8] AECOM for Zero Carbon Hub, *Carbon Emission Factors for Fuels - methodology and values for 2013 and 2016*, October 2010, http://www.zerocarbonhub.org/definition.aspx?page=8

standard should not be achieved at the expense of good place-making or by requiring house designs that look out of place. The Carbon Compliance Task Group considered that a requirement for roof-mounted solar technologies equivalent to 40% of ground floor area is the appropriate reference point for feasibility.

In the presentation of results for this additional modelling work, the percentage of ground floor area required to be used for roof-mounted solar technologies was again used as a proxy for feasibility, and results have been colour-coded depending on whether no PV is required to achieve a particular level; up to 25% ground floor area of solar technology is required; 25% to 40% of ground floor area of solar technology is required; over 40% of ground floor area of solar technology is required.

Range of carbon limits / carbon emission reductions modelled

The results of the modelling work undertaken are presented in the range of current (2010) regulations to the recommended Carbon Compliance limits for 2016.

It should be noted that the methodology underpinning the recommended 2016 standard differs in fundamental ways from the current Part L methodology:

- It is an 'as-built' rather than 'design' standard
- It is defined in terms of a limit on absolute CO_2 emissions per m² floor area per year ($kgCO_2/m^2.yr$)
- It is an Aggregate standard (different limits for different dwelling types)
- Fuel factors are not used
- The carbon emission factors are derived based on a 15-year forward looking average of marginal emissions and include upstream emissions and CO_2 equivalent emissions of other greenhouse gases

The modelling results are presented in both absolute terms and as a percentage reduction from 2006 Part L. The percentage reduction targets have been calculated without fuel factors to the following formula:

$TER = [C_H \times EFA_H + C_L \times EFA_L] \times (1 - 0.2) \times (1 - R)$

Where: R = the % reduction being examined (e.g. 0.25, 0.44, etc)

EFA_H = Emissions factor adjustment for gas relative to 2006 value

EFA_L = Emissions factor adjustment for electricity relative to 2006 value

EFA would be calculate to reflect each of the emissions factor scenarios being considered

Modelling results

Colour charts: feasibility

A number of colour charts have been produced (for each set of carbon emission factors) which indicate the technical feasibility for each house type modelled of combinations of fabric specification/ heat technology for the range of carbon emissions levels or carbon emissions reductions defined.

At the side of the table are the dwelling / technology options and across the top are the range of potential carbon emissions limits or percentage reductions from Part L 2006. For each dwelling / technology option PV (as a proxy) is used to the extent required to meet the particular carbon emissions limit or percentage reduction.

The results are colour-coded to indicate degrees of feasibility, based on the proportion of space required for solar technologies. Dark green indicates that the requirement can be comfortably met without the use of PV. Light green indicates that up to 25% ground floor area would have to be used for solar technologies. Yellow shows that solar technologies would be required to an area of between 25% and 40% of the ground floor area of the building. Orange indicates that the 40% figure has been exceeded. The number in the cell indicates the kWp PV required in order to meet the particular carbon emissions limit or percentage reduction.

An example section is included below. The full charts can be found in Appendix A1.

CC4TNH 2016 CO2 emission factors			Carbon emissions																	
$kgCO_{2(eq)}/m^2/yr$			20			19			18			17			16			15			14		
Detached House	Communal options	Biomass boiler																				
		Biomass CHP + Gas boiler																				
		Gas CHP + Biomass boiler																				
		Gas CHP + Gas boiler													0.0			0.3			0.6	0.1	
	Individual options	GSHP													0.2			0.5	0.2		0.8	0.5	
		ASHP + SHW																0.3			0.5	0.2	
		ASHP				0.1			0.4	0.0		0.6	0.3		0.9	0.6		1.2	0.8		1.5	1.1	0.1
		Direct Elec	4.1	3.2	0.2	4.3	3.5	0.5	4.6	3.8	0.8	4.9	4.1	1.1	5.2	4.3	1.3	5.4	4.6	1.6	5.7	4.9	1.9
		Gas boiler + SHW													0.1			0.3			0.6	0.2	
		Gas boiler							0.2			0.4	0.1		0.7	0.3		1.0	0.6		1.3	0.9	
End Terrace House	Communal options	Biomass boiler																				
		Biomass CHP + Gas boiler																				
		Gas CHP + Biomass boiler																				
		Gas CHP + Gas boiler										0.0			0.2			0.4	0.1		0.6	0.3	
	Individual options	GSHP	0.0			0.2			0.4			0.5			0.7	0.0		0.9	0.2	0.1	1.1	0.4	0.3
		ASHP + SHW							0.0			0.2			0.4	0.1		0.5	0.3		0.7	0.5	
		ASHP	0.5	0.3		0.7	0.4		0.9	0.6		1.0	0.8		1.2	1.0	0.1	1.4	1.2	0.3	1.6	1.3	0.5
		Direct Elec	3.4	2.8	0.4	3.5	3.0	0.5	3.7	3.2	0.7	3.9	3.3	0.9	4.1	3.5	1.1	4.2	3.7	1.2	4.4	3.9	1.4
		Gas boiler + SHW							0.0			0.2			0.4	0.1		0.6	0.3		0.7	0.5	
		Gas boiler	0.3	0.0		0.4	0.2		0.6	0.4		0.8	0.6		1.0	0.7		1.2	0.9		1.3	1.1	0.1

Figure 3: *Example section of colour chart showing feasibility of achievement of various absolute carbon targets. In this case central carbon emissions factors used (CC4TNH2016)*

Bar charts

The bar charts show how far fabric measures plus different heat technologies go to achieving carbon emissions limits or percentage reductions from 2006 Part L, for the three fabric levels modelled. These show how far one can go without requiring the generation of zero carbon electricity.

An example chart is shown below. The full suite of charts for the following heat technology scenarios can be found in Appendix A2: Gas boiler, Gas boiler + SHW, ASHP, ASHP + SHW, Gas CHP.

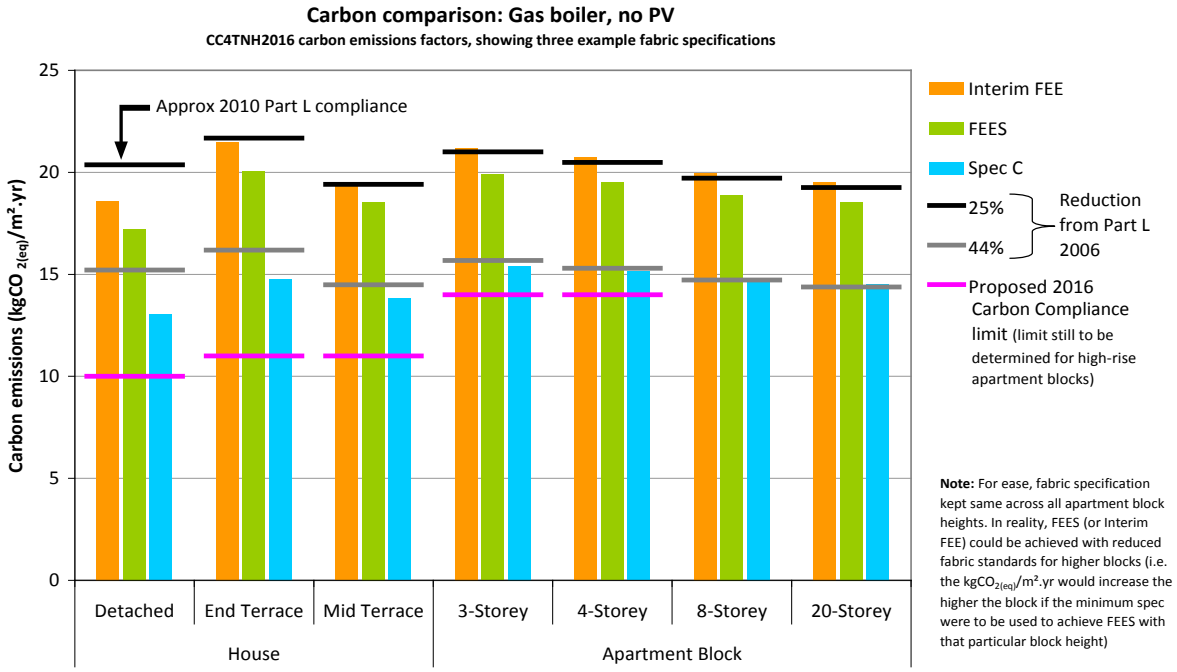


Figure 4: *Bar chart showing how much carbon reduction can be achieved for Gas heat technology for three example fabric specifications, without the use of zero carbon electricity. Central case carbon emission factors used (CC4TNH2016).*

Colour charts: CO_2 emission factor comparisons

Two charts have been developed to show the differences between the three carbon emission factor scenarios, and as compared to current 2010 emission factors. For ease, these look at the gas boiler and ASHP cases only, for all dwelling types. The colour coding is the same as described above for the feasibility colour charts. These charts are available in Appendix A3.

A third chart showing the absolute regulated carbon emissions from the relative carbon reduction cases (percentage reduction from 2006 Part L) is also provided in Appendix A4. In this, the number in the coloured box is the $kgCO_2/m^2/yr$ DER which relates to the particular percentage reduction and carbon emission factor scenario combination.

Commercial issues

Overview of methodology

Capital and lifecycle costs were analysed for each of the dwelling types on the basis of different fabric specifications, services and renewable energy technologies. In combination with the technical analysis, the commercial information is used to assess the impact of requiring different TER on capital costs, Net Present Value (NPV), running costs and cost effectiveness (£ per tonne of CO_2e saved over 60 years).

Cost analysis was undertaken by Cyril Sweett using information gathered from industry and its own internal cost data. The costs associated with different fabric standards were gathered specifically for this study while costs for building services and renewable energies are drawn from recent work on the Carbon Compliance standard.

Cost models

To analyse the capital cost implications of the three different fabric specifications, 'Interim FEE', 'FEES' and 'Spec C', elemental cost models were developed for each of the core dwelling types considered by the Technical Work Group; small flats, large flats, mid terraced houses, end terraced houses and detached houses.

The flats units were evaluated within the context of cost models for four scales of apartment building: 3, 4, 8 and 20 storeys. Each floor within each building deemed to comprise four small flats and four large flats.

The house types were modelled as individual dwellings.

The cost models were constructed to be representative of buildings of mid-market quality constructed at costs broadly equating to UK mean price levels at 2Q 2011.

	3-storey apartment block	4-storey apartment block	8-storey apartment block	20-storey apartment block	Mid-terrace house	End – terrace house	Detached house
GIFA per unit (m^2)*	59.38	60.52	66.18	68.46	76.32	76.32	117.92
Build cost (£/unit)	75,000	78,000	88,000	120,000	76,000	80,000	109,000
Build cost (£/m^2 GIFA)	1,264	1,287	1,333	1,751	998	1,050	921

* Gross internal floor areas (GIFA) for the apartment buildings are the average for all units within the building including a proportion of common area space

Figure 5: *Summary of costs for base building types*

Whilst the house types are modelled on an individual dwelling basis, it is assumed that they would be built as part of a small plot development of say, 20 units.

In respect of building fabric, the cost models are assumed compliant with Building Regulations Part L 2010. The cost models also include allowance for:

- main contractor preliminaries
- main contractor overheads & profit
- construction contingency

The baseline performance of each home is 2010 compliant (see specifications in Appendix B1). All homes are assumed to be 'on gas' with the baseline house being heated by a gas boiler with cylinder. Low rise (below 5 storeys) apartments are assumed to have combi boilers while higher rise blocks

would have a centralised gas fired hot water system. The results presented in this study would vary for off gas properties because, for example, the costs of achieving compliance with Part L 2010 and the associated running costs would be different to those for on gas units.

No allowance is made within the cost models for low or zero carbon technologies. These are considered separately in this report.

The cost models also exclude:

- site abnormal costs
- design fees
- VAT

Fabric specification

The fabric standards costed in this report draw on the work carried out for the Zero Carbon Hub's 2009 work on energy efficiency[9].

The measures deemed necessary to achieve each standard, and indeed the costs themselves, have been considered afresh in this report using current experience, data and, in some instances, the results of third party consultation available.

In particular, the building services costs have been drawn from Cyril Sweett's own project experience and a survey of house builders and suppliers. All cost analysis is based on the use of 'traditional' masonry construction methods. For some fabric specifications, e.g. where very high levels of air tightness and/or low thermal bridging is required, some developers might consider alternative methods such as framed or SiP systems.

Air tightness and thermal bridging

Achieving higher performance standards for air tightness and thermal bridging forms an important component of the selected compliance route for achieving FEES and more advanced standards (e.g. Spec C). At present the industry has relatively little experience of consistently achieving these standards with 'traditional' masonry construction. The cost implications assumed of improving performance in these areas are shown below together with assessment of the extent to which these initial cost are likely to diminish over time.

Measure	Cost (£ for end terrace house)		Diminish over time	Fixed (subject to learning)
	~3 $m^3/m^2/hr$	~1 $m^3/m^2/hr$		
Changes to specifications, additional materials etc.	200	500		Y
Enhanced detailing, sealing at junctions	115	115		Y
Enhanced levels of management control, training etc	250	500	Y	
Additional testing (@ £500 per test)	50	125		Y
Total	**615**	**1240**		

Figure 6: *Summary of costs for achieving airtightness levels of 3 and 1 $m^3/m^2.hr$*

[9] *Defining a Fabric Energy Efficiency Standard for Zero Carbon Homes, Zero Carbon Hub (November 2009)*

Measure	Cost (£ for end terrace house)		Diminish over time	Fixed (subject to learning)
	0.06 W/m²K	0.04 W/m²K		
High spec linter closers	300 - 370			Y
Enhanced closers for jambs and sills				Y
Split lintels				Y
Additional sealing to joints	0	250		Y
Additional design time	100		Y	
Additional calculations	0	200	Y	
Total	**~ 450**	**~ 900**		

Figure 7: *Summary of costs for achieving thermal bridging levels of 0.06 and 0.04 W/m²K*

An indicative assessment of the impact of learning on the costs associated with air tightness and thermal bridging suggests that relative[10] costs will reduce in the future as the specifications become more widely adopted.

The speed of learning is influenced by the rate of uptake of the standards in question. There is likely to be a general increase in adoption as a result of standards such as the Code for Sustainable Homes or PassivHaus, however its inclusion as a minimum requirement in Part L will be the key factor influencing the scale of adoption.

Based on estimated levels of uptake it is projected that if Part L were to require the adoption of FEES in 2013 the costs in 2014 would be reduced to approximately 40% of their current (2011) cost, if Part L 2013 does not include a requirement for FEES it is likely that less learning would arise and the cost premium associated with air tightness and thermal bridging would be approximately 65% of current costs.

Capital cost analysis

Capital cost estimates were compiled on an elemental basis to show the extra over costs of achieving different carbon compliance levels in comparison to a 2010 compliant home. Each cost estimate comprised three elements:

- fabric energy efficiency –the 'Interim FEES', FEES or a more advanced standard (Spec C) that approaches PassivHaus performance
- core heating technology(ies) – individual and shared technologies of different sizes were assessed in isolation, or in selected combinations (eg ASHP and SWH)
- renewable electricity - using the cost of PV as a proxy. PV was added to each technology option to the extent required to achieve a target carbon compliance level. The quantity required was defined by the technical studies. The cost of PV was divided into fixed and marginal cost elements: fixed costs comprising installation, connection and some inverter cost; marginal cost comprising allowance for increasing panel area and some additional inverter cost

[10] This analysis makes no allowance for changes in underlying construction costs.

Cost estimates were derived from a survey of builders and installers, together with Cyril Sweett's in house cost data. As applicable, the cost estimates include for:

- the core material or specification change or core technology
- connections, fuel delivery mechanisms, onsite upgrades to electrical infrastructure to support the use of heat pumps[11], etc
- additional preliminaries specifically required to facilitate the introduction of a new technology; i.e. scaffolding hire for installation of solar technologies
- additional space requirements; e.g. in respect of biomass boilers and fuel storage
- general builders work in connection
- subcontractor preliminaries, overheads & profit

No allowance has been made for:

- changes in main contractor's general preliminaries costs
- changes in main contractor's overheads & profit
- additional design cost (main contractor / house builder); other than in the case of the air tightness improvements
- contingency
- grants or any capitalisation of Feed-in-tariff revenue
- VAT

As noted above, a survey of housebuilders and technology suppliers was used to update cost benchmarks for a range of defined building services systems. The market analysis revealed significant variations in the costs experienced across the housing industry even after costs were adjusted for consistency by standardising:

- **quality thresholds** – to mid range commercially available levels likely to be installed by a house builder and obtained in a competitive procurement process
- **scope** – to ensure consistent inclusions and exclusions (see previous)
- **scale** - price data assumes that the technology is being procured to match a development of broadly 200 units or less
- **site conditions** - sites were assumed to be free of constraints brought about by location specific abnormals such as challenging ground conditions, sequencing, and logistics

Lifecycle costs

Lifecycle cost analysis incorporated a wide range of costs and benefits arising over a 60 year time period. This analysis enabled assessment of the potential impact of different options on household costs and on their cost effectiveness as a means of reducing carbon emissions.

Inputs to the lifecycle model were:

- Cost
    - Capital cost (see previous)
    - Planned maintenance
    - Operational costs
    - Replacement (part or full)

[11] Any offsite impacts on electrical infrastructure were excluded (see Policy issues).

- Learning rates – a percentage reduction in cost forecast from modelling of effects of learning in the global and national supply chain for each fabric, building service option.
- Energy / fuel
    - Energy consumption (electricity, gas, and biomass) – from the technical modelling
    - Fuel costs (electricity, gas and biomass) – both consumer and variable[12] energy price projections were taken from guidance published by the Department for Energy and Climate Change[13]
    - Carbon emission factors (electricity, gas and biomass) – from the technical modelling
    - Revenue for sales of generated electricity into the national grid – pricing taken at £0.03 per kWh as per FiT.
    - (optionally) Revenue from feed-in tariff (FiT) and renewable heat incentive (RHI[14]) – FiT tariff's digressed to the completion year of the property
- Modelling variables
    - Year of property completion (eg 2016)
    - Study period (up to 60 years)
    - Discount rate (default of 3.5%)
    - Percentage of electricity generated that is exported to the grid (default of 50%)
    - Inclusion / exclusion of income from FiT or RHI

The model provides a full breakdown of annual financial costs and revenues and the carbon emissions associated with achieving a given TER for a home with a specified combination of fabric performance and building services. This information is then used to calculate the present (discounted) value of all the future costs and revenues to determine the net present value of the option in comparison to a home built to the requirements of Building Regulations Part L 2010. The costs and revenue information generated by the model was used to provide the following analyses:

- **Potential impact on householder costs** – by summing the present value of ongoing costs and revenues but excluding the capital cost (incurred by the developer). NB. It should be remembered that this is only a potential saving and that under some circumstances (eg the involvement of an Energy Services Company or alternative third party) part or all of any benefit would be taken by others
- **Cost effectiveness of carbon savings (£ per tonne of CO_2e saved)** – by dividing the sum of present value costs and revenues by the tonnes of CO_2e saved over the lifecycle period. NB. For this analysis the variable cost of energy is used as this reflects the costs to the UK as a whole rather than the cost to the consumer.

Results

Results are presented for capital cost, householder costs and overall cost effectiveness. Given the potential variability in costs associated with air tightness and thermal bridging, the results are presented both with and without allowances for these costs.

[12] Variable energy prices exclude taxes and fixed operating costs and therefore provide a measure of the marginal social cost of using a unit of energy.

[13] Valuation of energy use and greenhouse gas emissions for appraisal and evaluation, DECC, June 2010.

[14] Renewable Heat Incentive revenue is based on published tariff levels (March 2011) and exclude ASHP

Capital costs for fabric options (including costs for air tightness and thermal bridging)

The tables and graph below summarises the estimated cost changes for each category of fabric specification against a '2010 compliant' baseline. The cost estimates include allowance for improved air tightness and thermal bridging using the budgets described on Page 11.

Summary of fabric cost impact including airtightness and thermal bridging

	3-storey apartment block	4-storey apartment block	8-storey apartment block	20-storey apartment block	Mid-terrace house	End – terrace house	Detached house
£/unit	-£415	£413	-£527	-£500	-£39	£176	£2,320
£/m² GIFA	-£7	-£7	-£8	-£7	-£1	£2	£20
% increase over cost model	-0.55%	-0.53%	-0.60%	-0.42%	-0.05%	0.22%	2.15%

***Figure 8**: Cost impact of '**Interim FEE**' (incl. airtightness & thermal bridging)*

	3-storey apartment block	4-storey apartment block	8-storey apartment block	20-storey apartment block	Mid-terrace house	End – terrace house	Detached house
£/unit	£726	£716	£726	£722	£939	£1,540	£3,913
£/m² GIFA	£12	£12	£11	£11	£12	£20	£33
% increase over cost model	0.97%	0.92%	0.82%	0.60%	1.24%	1.92%	3.62%

***Figure 9**: Cost impact of '**FEES**' (incl. airtightness & thermal bridging)*

	3-storey apartment block	4-storey apartment block	8-storey apartment block	20-storey apartment block	Mid-terrace house	End – terrace house	Detached house
£/unit	£3,816	£3,826	£4,214	£4,222	£4,942	£5,895	£8,872
£/m² GIFA	£64	£63	£64	£62	£65	£77	£75
% increase over cost model	5.09%	4.91%	4.79%	3.52%	6.50%	7.37%	8.21%

***Figure 10**: Cost impact of '**Spec C**' (incl. airtightness & thermal bridging)*

Capital costs for fabric options (excluding costs for air tightness and thermal bridging)

The tables and graph below summarises the estimated cost changes for each category of fabric specification against a '2010 compliant' baseline. The cost estimates exclude allowance for improved air tightness and thermal bridging.

Summary of fabric cost impact excluding any costs for improved air tightness and thermal bridging

	3-storey apartment block	4-storey apartment block	8-storey apartment block	20-storey apartment block	Mid-terrace house	End – terrace house	Detached house
£/unit	-£441	-£444	-£582	-£563	£255	£176	£642
£/m² GIFA	-£7	-£7	-£9	-£8	£3	£2	£5
% increase over cost model	-0.59%	-0.57%	-0.66%	-0.47%	0.34%	0.22%	0.59%

***Figure 11**: Cost impact of '**Interim FEE**' (excl. airtightness & thermal bridging)*

	3-storey apartment block	4-storey apartment block	8-storey apartment block	20-storey apartment block	Mid-terrace house	End – terrace house	Detached house
£/unit	£137	£119	£92	£73	£489	£492	£1,649
£/m² GIFA	£2	£2	£1	£1	£6	£6	£14
% increase over cost model	0.18%	0.15%	0.10%	0.06%	0.64%	0.61%	1.53%

***Figure 12**: Cost impact of '**FEES**' (excl. airtightness & thermal bridging)*

	3-storey apartment block	4-storey apartment block	8-storey apartment block	20-storey apartment block	Mid-terrace house	End – terrace house	Detached house
£/unit	£2,417	£2,406	£2,689	£2,657	£3,489	£3,841	£5,682
£/m² GIFA	£41	£40	£41	£39	£46	£50	£48
% increase over cost model	3.22%	3.09%	3.06%	2.21%	4.59%	4.80%	5.26%

***Figure 13**: Cost impact of '**Spec C**' (excl. airtightness & thermal bridging)*

Figure 14 below summarises these additional costs for housing and 4 storey apartments showing the build up of additional cost items and the total % impact on cost with and without costs for enhanced air tightness and thermal bridging.

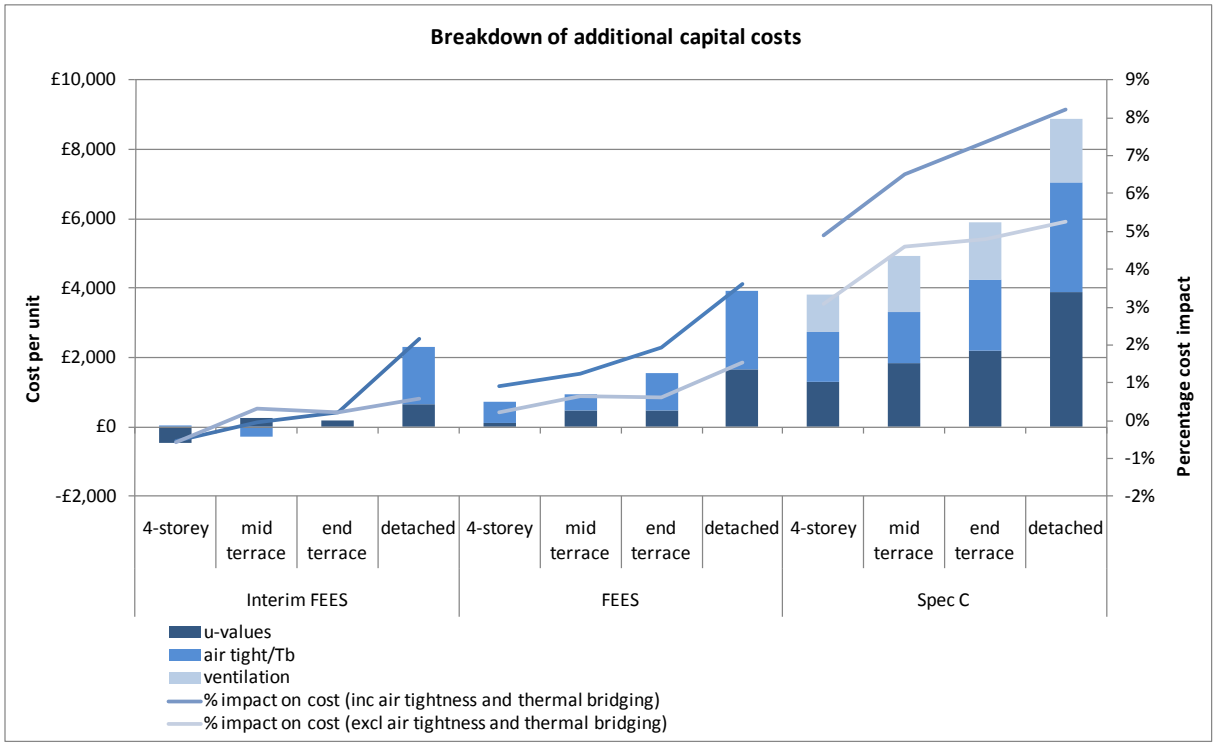


***Figure 14:** Capital cost impact of achieving varying building fabric performance standards*

Capital costs for building services and renewable energy technologies

The table below shows the capital costs of heating and hot water technologies for each of dwelling type. The costs are net of the baseline case of a gas boiler (centralised heating in high rise apartments, combi in low rise apartments, boiler and cylinder in houses).

	3-storey apt block, ave per unit	4-storey apt block, ave per unit	8-storey apt block, ave per unit	20-storey apt block, ave per unit	ZCH Mid terrace house	ZCH End terrace house	ZCH Detached house
Individual technologies							
Direct electric	-£350	-£350	-£1,500	-£1,000	-£500	-£500	-£500
Gas (baseline)	**£0**	**£0**			**£0**	**£0**	**£0**
Gas + SHW					£3,679	£3,679	£3,759
ASHP	£6,043	£6,043			£5,788	£5,788	£6,530
ASHP + SHW					£9,075	£9,075	£9,855
GSHP (houses only)					£10,120	£10,120	£10,120
Shared technologies							
Gas centralised			**£0**	**£0**			
Gas + SHW	£8,442	£7,360					
ASHP	£6,814	£6,007	£640	£270			
ASHP + SHW	£9,683	£8,622					
Biomass boiler	£8,571	£7,582	£1,812	£1,468	£5,425	£5,425	£5,425
Gas CHP + Gas	£8,615	£7,611	£2,329	£1,961	£6,038	£6,038	£6,038
GSHP	£9,255	£8,361	£3,334	£2,774	£7,480	£7,480	£7,480

Figure 15: *Capital cost impact of heat producing technologies*

Costs for photovoltaic systems were determined based on a combination of a defined fixed cost of £900 per installation and a further variable cost of £3730 per kWp.

Combined capital costs to achieve defined carbon targets

Figures 16 to 19 show the combined (fabric, services and renewables) capital cost impact of achieving different carbon targets for an end terrace house and a 4 storey apartment, built to the FEES fabric specification. Results are shown both with and without cost allowance for air tightness and thermal bridging.

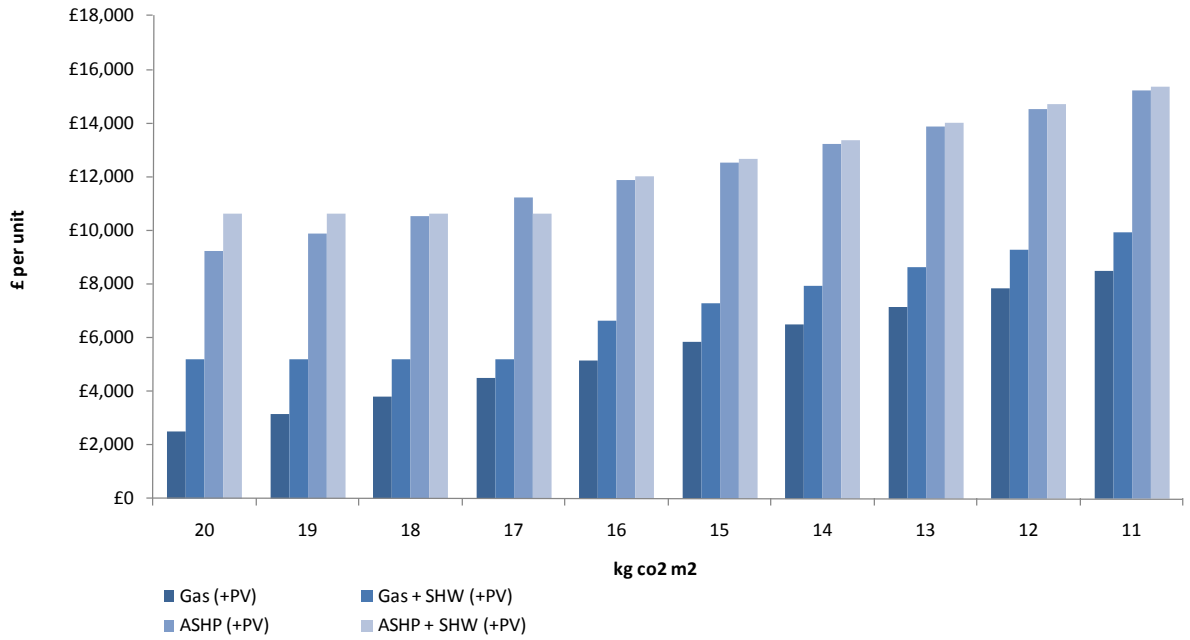


***Figure 16**: Capital cost impact of achieving defined carbon targets (20 to 11 kg $CO_2/m^2.yr$) for an **end terrace house** built to the FEES fabric specification (**including** air tightness and thermal bridging)*

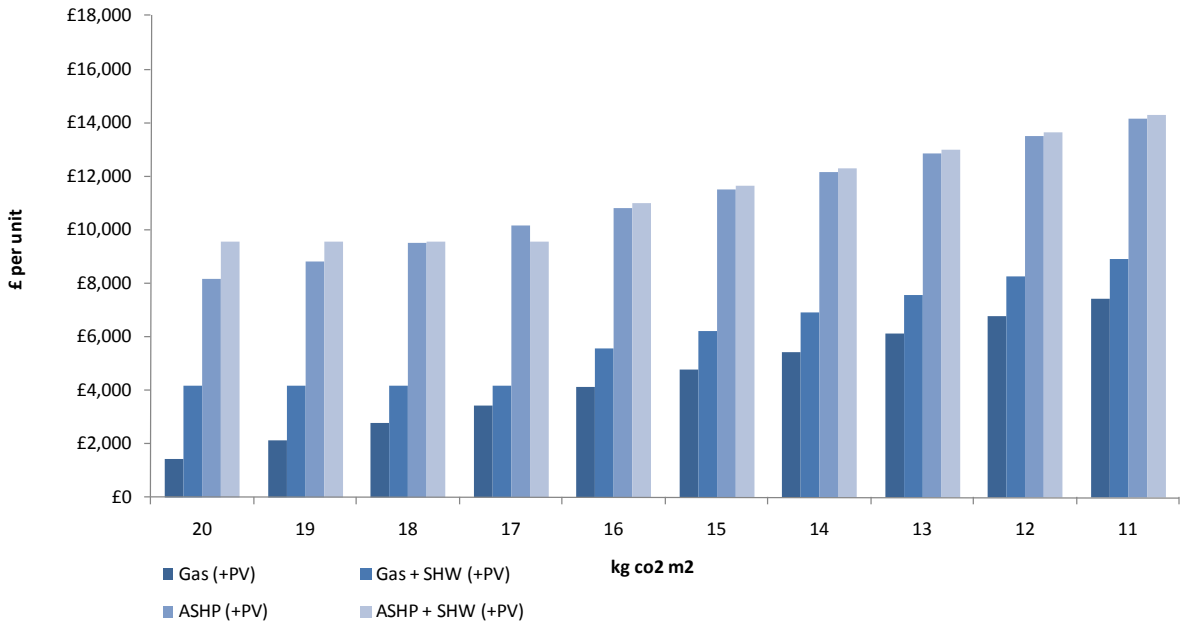


***Figure 17:** Capital cost impact of achieving defined carbon targets (20 to 11 kg $CO_2/m^2.yr$) for an **end terrace house** built to the FEES fabric specification (**excluding** air tightness and thermal bridging)*

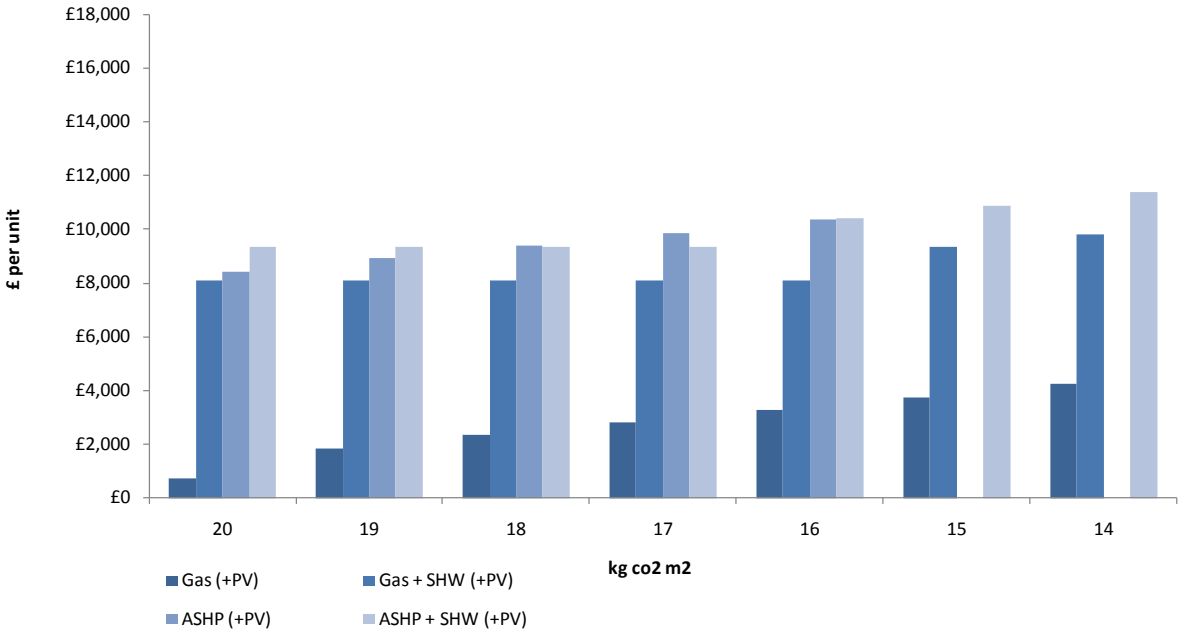


Figure 18: *Capital cost impact of achieving carbon targets (20 to 14 kg $CO_2/m^2.yr$) for a* ***4 storey apartment block*** *built to the FEES fabric specification (**including** air tightness and thermal bridging)*

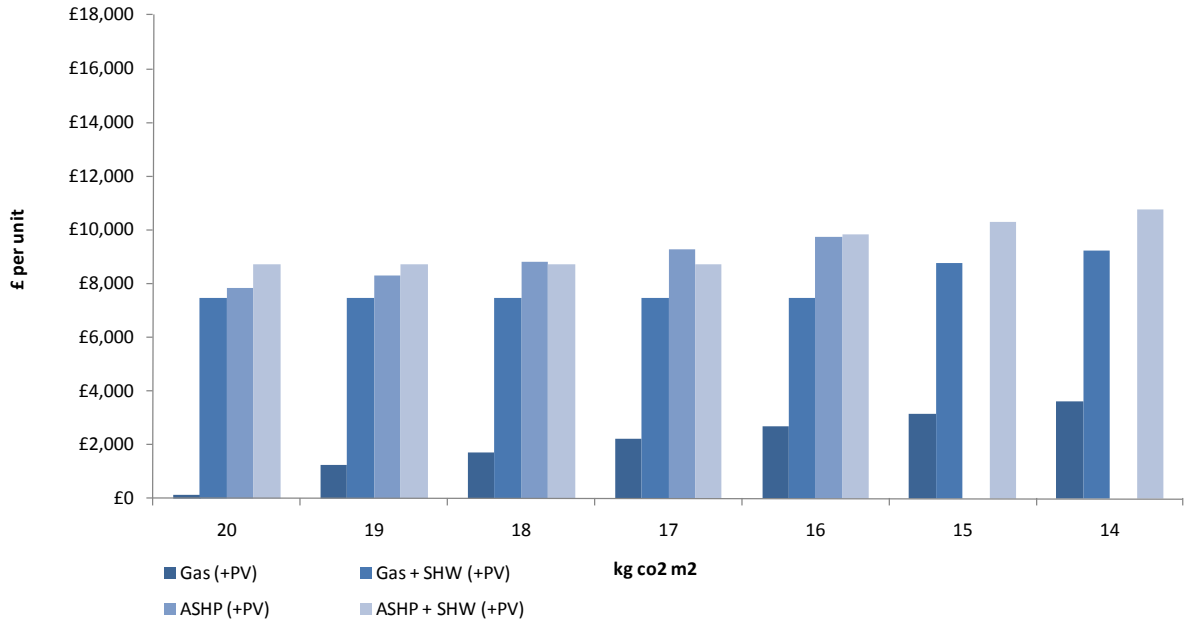


Figure 19: *Capital cost impact of achieving carbon targets (20 to 14 kg $CO_2/m^2.yr$) for a* ***4 storey apartment block*** *built to the FEES fabric specification (**excluding** air tightness and thermal bridging)*

The sensitivity of these costs to fabric specification is shown in Figures 20 and 21, where costs of the least expensive services and renewables option (a gas boiler and PV) are shown with different fabric standards (both including and excluding costs for air tightness and thermal bridging).

Spec C 'overshoots' the carbon target down to 14kgCO_2/m²/yr, which is why the bar height remains constant to this point.

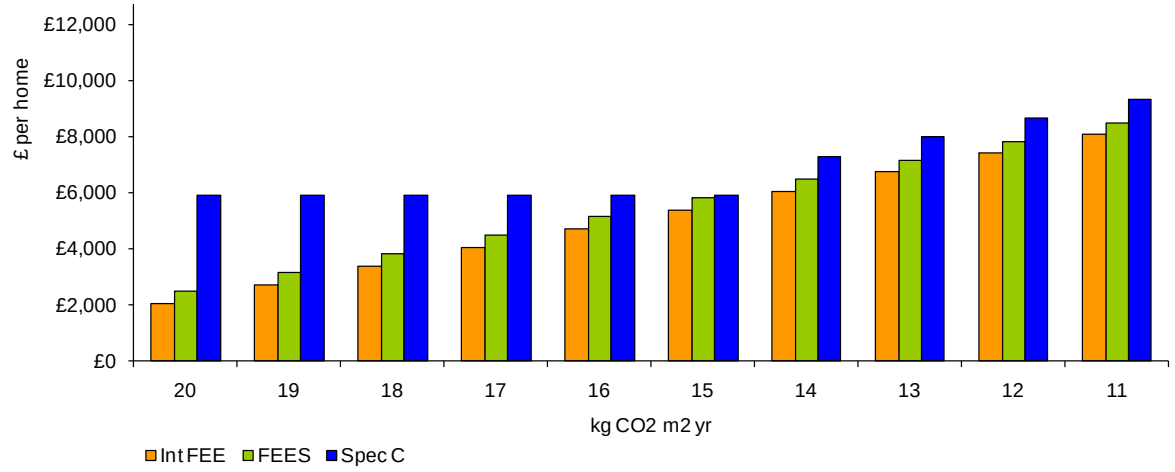


Figure 20: *Capital cost impact of achieving defined carbon targets (20 to 11 kg CO_2/m^2.yr) for an* ***end terrace house*** *built to the different fabric specifications (****including*** *air tightness and thermal bridging)*

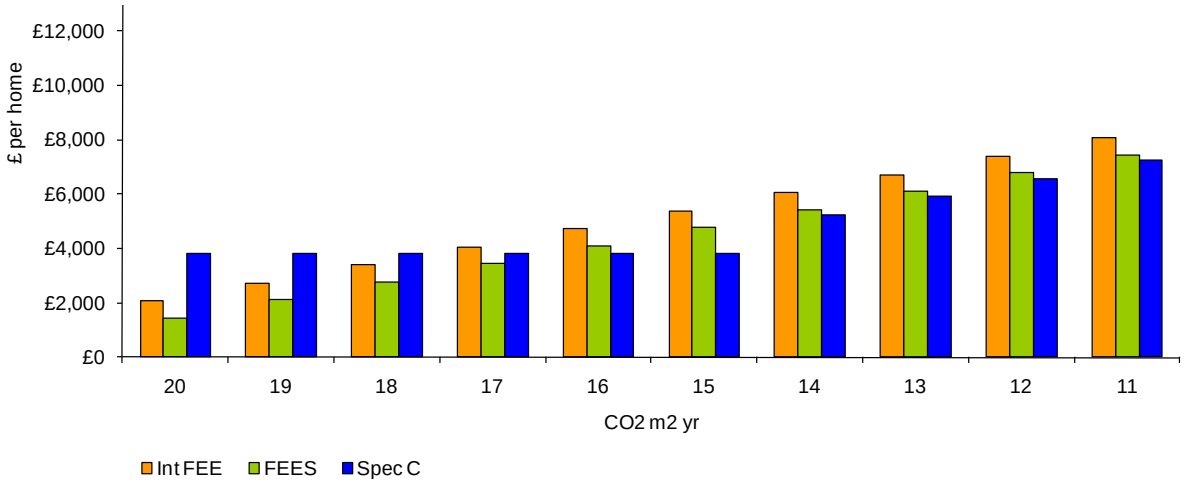


Figure 21: *Capital cost impact of achieving defined carbon targets (20 to 11 kg CO_2/m^2.yr) for an* ***end terrace house*** *built to the different fabric specifications (****excluding*** *air tightness and thermal bridging)*

Household costs

Figures 22 to 25 show the impact of achieving carbon targets between 20 and 11 kg CO_2/m².yr on the 60 year present value of household running costs[15] for an end terrace house using either gas or ASHP technologies. In all cases the baseline over which the costs are shown is a 2010 gas boiler compliant case.

The results are presented both with and without income from the FiT / RHI. It should be noted that Spec C+ various combinations 'overshoots' the carbon target down to: 14kgCO_2/m².yr for gas boiler, 11kgCO_2/m².yr for gas boiler+ SHW , 16kgCO_2/m².yr for ASHP, and 11kgCO_2/m².yr for ASHP + SHW.

[15] Household running costs includes domestic energy prices and operating, maintenance and replacement costs.

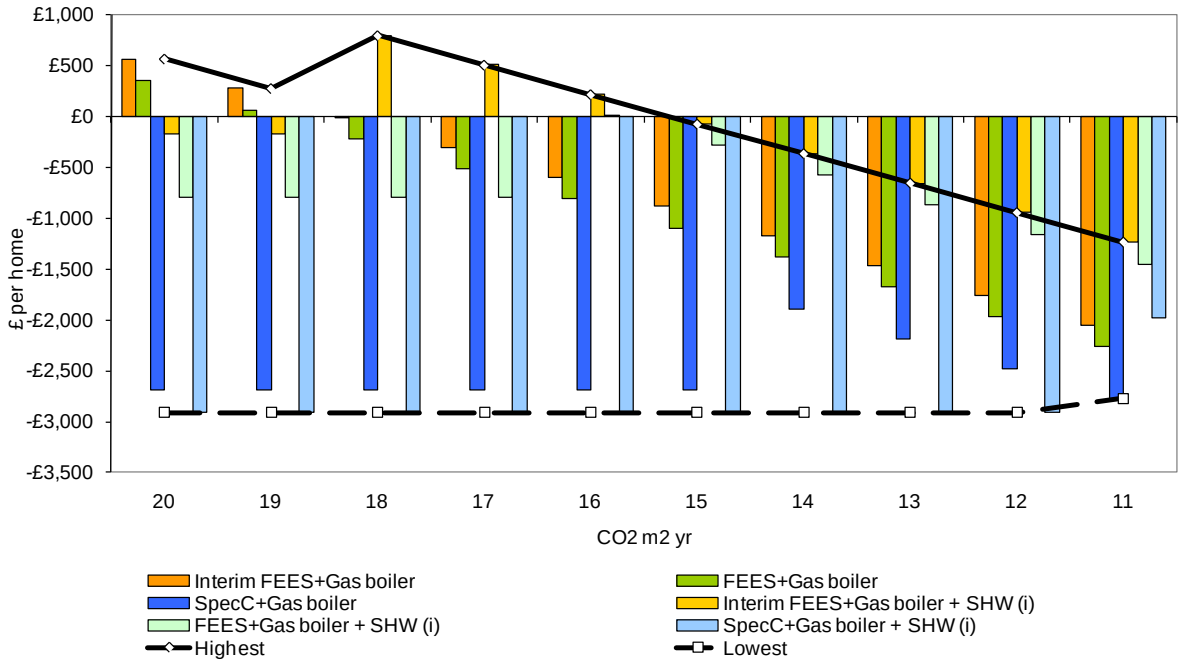


Figure 22: *Impact on running costs for an* ***end terrace house*** *with different technologies (****Gas****) and fabric standards,* ***excluding FiT and RHI***

Without FiT / RHI Running costs are lowest for the most thermally efficient properties, running costs are high where very little PV is used because the fixed maintenance and replacement costs are greater than the value of the energy saved.

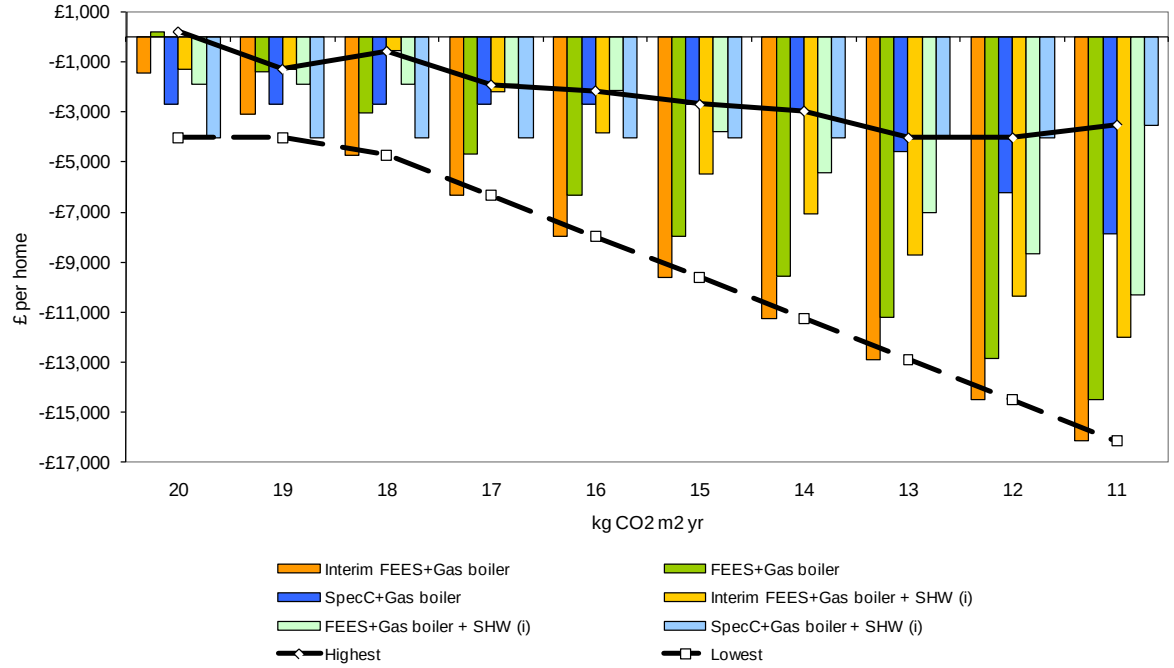


Figure 23: *Impact on running costs for* ***an end terrace house*** *with different technologies (****Gas****) and fabric standards,* ***including FiT and RHI***

When FiT / RHI is included, savings increase more significantly with greater use of PV. This means that the less thermally efficient home have lower net running costs because greater quantities of PV were installed to achieve the TER.

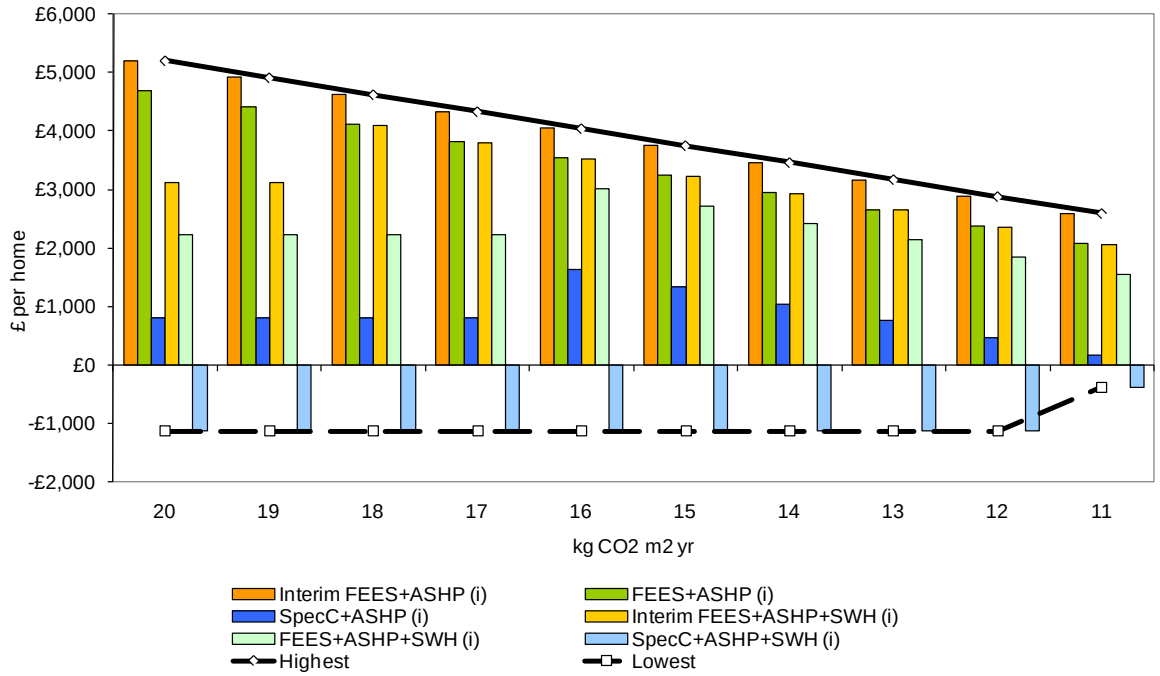


Figure 24: *Impact on running costs for an* ***end terrace house*** *with different technologies (****ASHP****) and fabric standards,* ***excluding FiT and RHI***

Without FiT or RHI the running costs of ASHP based solutions are generally higher than for a 2010 compliant home with gas heating.

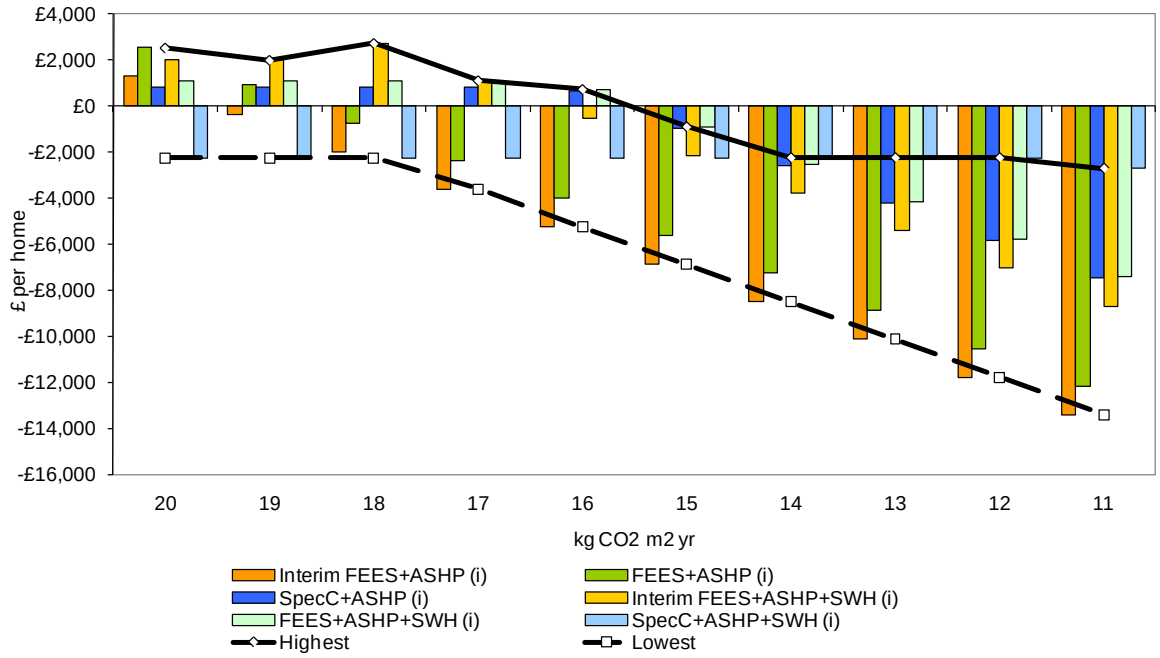


Figure 25: *Impact on running costs for an* ***end terrace house*** *with different technologies (****ASHP****) and fabric standards,* ***including FiT and RHI***

The inclusion of FiT and RHI delivers savings in comparison to a 2010 compliant property. These benefits increase in proportion to the use of PV and so are highest for the least thermally efficient properties.

Net present value

Figures 26 to 28 show the NPV of 60 year costs and benefits[16] associated with achieving TERs between 20 and 11 kg $CO_2/m^2.yr$ for an end terrace house. The following illustrations are shown:

- Gas boiler, including allowance for air tightness and thermal bridging
- Gas boiler, excluding allowance for air tightness and thermal bridging
- ASHP, including allowance for air tightness and thermal bridging

It should be noted that Spec C+ various combinations 'overshoots' the carbon target down to: $14kgCO_2/m^2.yr$ for gas boiler, $11kgCO_2/m^2.yr$ for gas boiler+ SHW , $16kgCO_2/m^2.yr$ for ASHP, and $11kgCO_2/m^2.yr$ for ASHP + SHW.

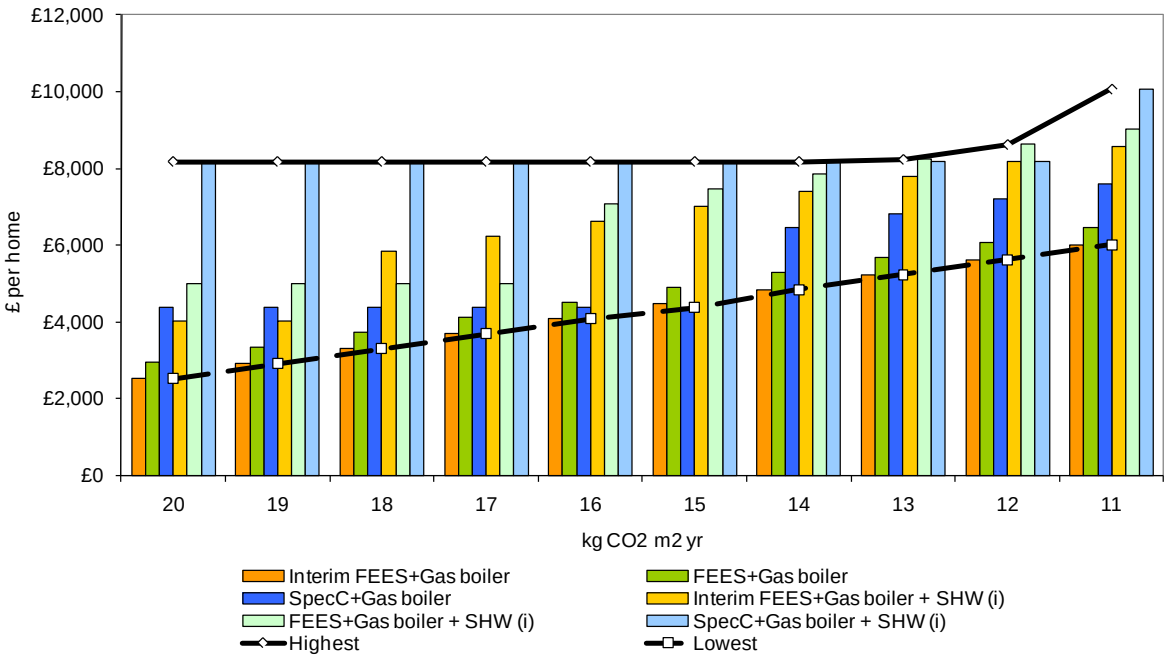


Figure 26: *Net present value of achieving different carbon targets for* ***an end terrace house*** *with different technologies (****Gas****) and fabric standards,* ***includes*** *allowance for enhanced air tightness and thermal bridging*

Generally NPV is lowest (i.e. lowest net cost) with the Interim FEE specification although at $14kgCO_2/m^2$ the Spec C specification has a slightly lower NPV as at this stage there is still no need to use PV.

[16] Costs and benefits include the capital cost, the variable energy price (ie excluding taxes and fixed generating costs), operating, maintenance and replacement costs. FiT and RHI payments are excluded.

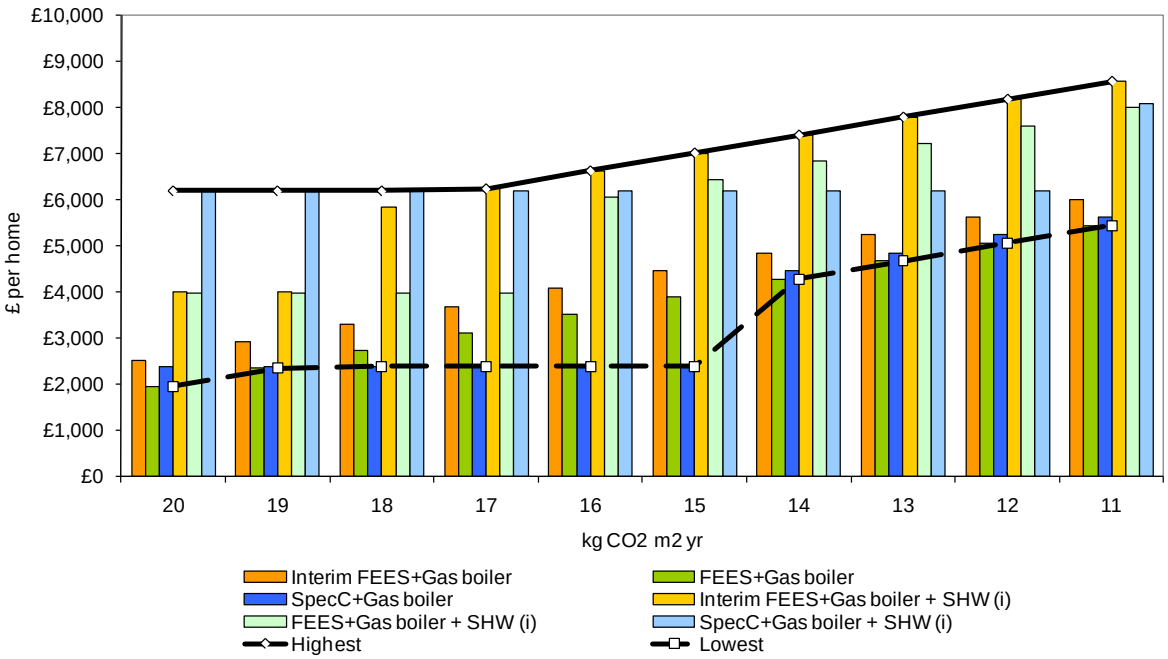


Figure 27: *Net present value of achieving different carbon targets for an* ***end terrace house*** *with different technologies and fabric standards (****Gas****),* ***excludes*** *allowance for enhanced air tightness and thermal bridging*

If costs associated with achieving enhanced air tightness and thermal bridging are excluded then the FEES and Spec C standards have a lower NPV than Interim FEES.

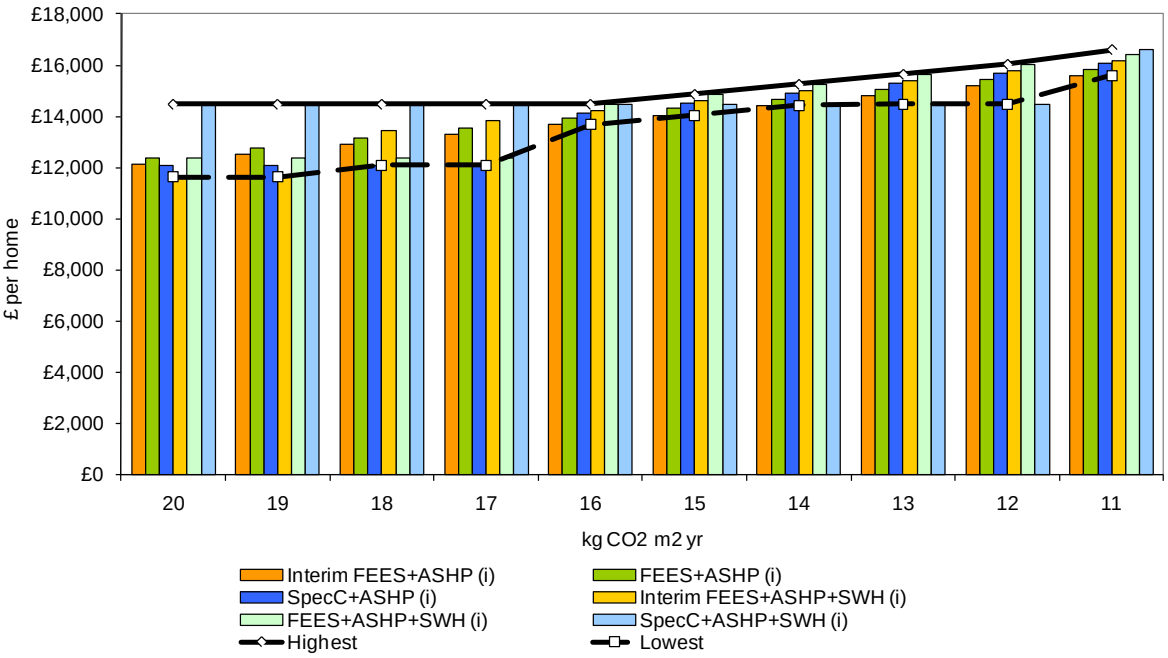


Figure 28: *Net present value of achieving different carbon targets for an* ***end terrace house*** *with different technologies and fabric standards (****ASHP****),* ***includes*** *allowance for enhanced air tightness and thermal bridaina.*

Cost effectiveness

Figures 29 to 31 show the costs effectiveness of carbon savings achieved when TER levels are between 20 and 11 kg $CO_2/m^2.yr$ for an end terrace house. The following illustrations are shown:

- Gas boiler, including allowance for air tightness and thermal bridging
- Gas boiler, excluding allowance for air tightness and thermal bridging
- ASHP, including allowance for air tightness and thermal bridging

It should be noted that Spec C+ various combinations 'overshoots' the carbon target down to: $14kgCO_2/m^2.yr$ for gas boiler, $11kgCO_2/m^2.yr$ for gas boiler+ SHW , $16kgCO_2/m^2.yr$ for ASHP, and $11kgCO_2/m^2.yr$ for ASHP + SHW.

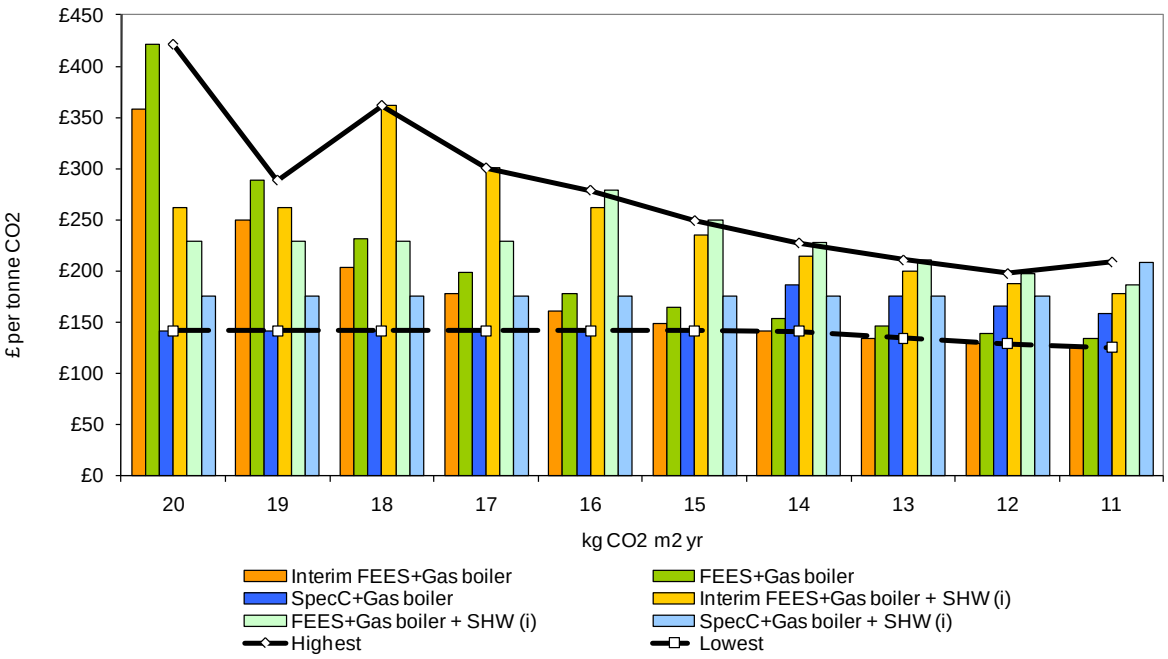


Figure 29: *Cost effectiveness of achieving different carbon targets for an* ***end terrace house*** *with different technologies (****Gas****) and fabric standards,* ***includes*** *allowance for enhanced air tightness and thermal bridging.*

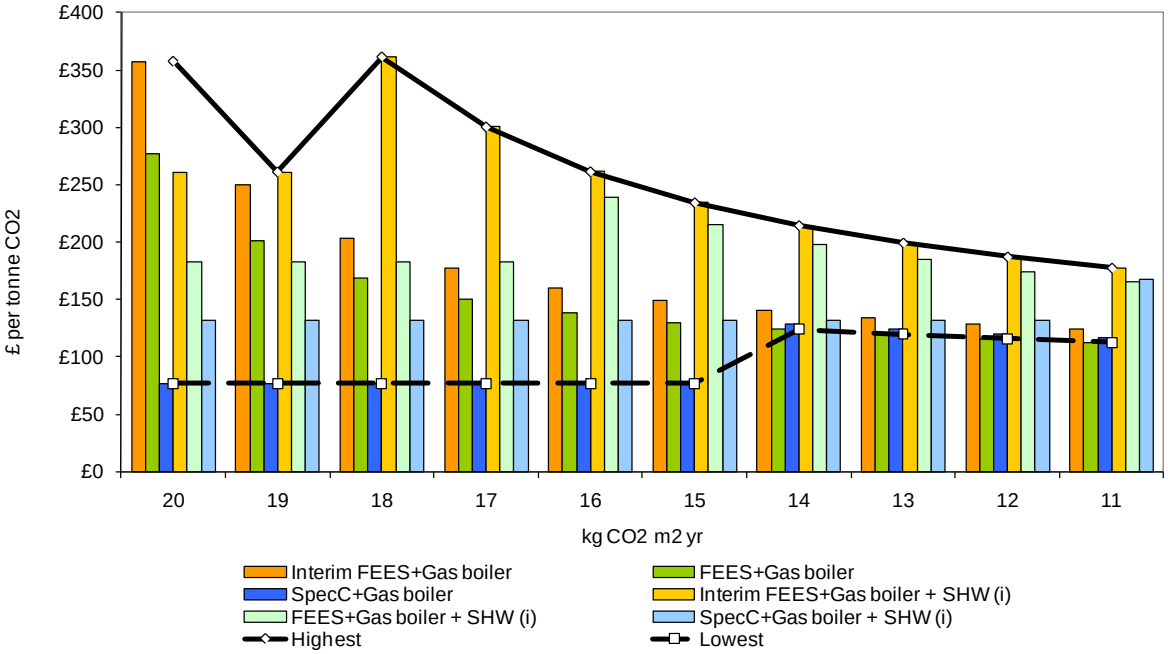


Figure 30: *Cost effectiveness of achieving different carbon targets for an* ***end terrace house*** *with different technologies (****Gas****) and fabric standards,* ***excludes*** *allowance for enhanced air tightness and thermal bridging.*

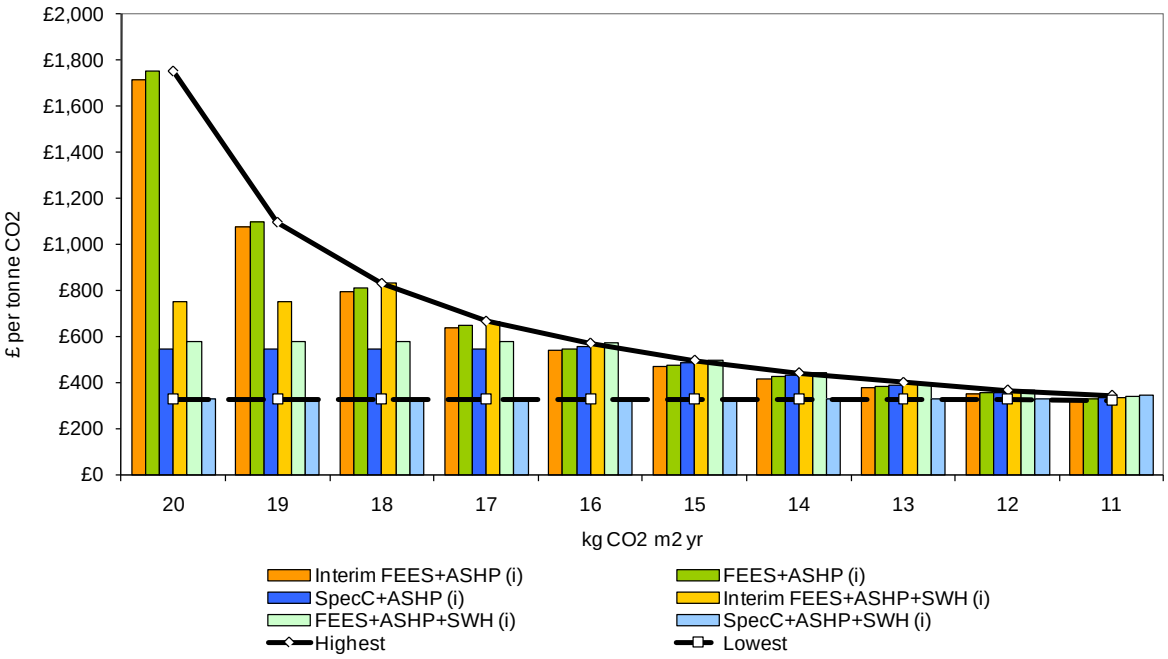


Figure 31: *Cost effectiveness of achieving different carbon targets for an* ***end terrace house*** *with different technologies (****ASHP****) and fabric standards,* ***includes*** *allowance for enhanced air tightness and thermal bridging.*

For all scenarios, it is most cost effective to move to the Spec C level for targets above 14 kg CO_2 m^2. This is because the amount of carbon saved at each TER level is beyond that required for compliance.

Appendix A1

Feasibility colour charts:

- Absolute emissions; emissions factor scenario CC4TNH2016
- Absolute emissions; emissions factor scenario CC4TNH2013
- Absolute emissions; emissions factor scenario DECC2013
- Relative emissions reduction; emissions factor scenario CC4TNH2016
- Relative emissions reduction; emissions factor scenario CC4TNH2013
- Relative emissions reduction; emissions factor scenario DECC2013

CC4TNH 2016 CO2 emission factors

Carbon emissions

$kgCO_{2(eq)}/m^2/yr$

			20			19			18			17			16			15			14			13			12			11			10		
Detached House	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																								0.1			0.4			0.7	0.2	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler													0.0			0.3			0.6	0.1		0.9	0.4		1.1	0.7		1.4	1.0		1.7	1.2	
	Individual options	**GSHP**													0.2			0.5	0.2		0.8	0.5		1.0	0.8	0.0	1.3	1.0	0.3	1.6	1.3	0.6	1.9	1.6	0.8
		ASHP + SHW																0.3			0.5	0.2		0.8	0.5		1.1	0.7		1.4	1.0		1.6	1.3	0.2
		ASHP				0.1			0.4	0.0		0.6	0.3		0.9	0.6		1.2	0.8		1.5	1.1	0.1	1.7	1.4	0.3	2.0	1.7	0.6	2.3	1.9	0.9	2.6	2.2	1.2
		Direct Elec	4.1	3.2	0.2	4.3	3.5	0.5	4.6	3.8	0.8	4.9	4.1	1.1	5.2	4.3	1.3	5.4	4.6	1.6	5.7	4.9	1.9	6.0	5.2	2.2	6.3	5.4	2.4	6.5	5.7	2.7	6.8	6.0	3.0
		Gas boiler + SHW													0.1			0.3			0.6	0.2		0.9	0.5		1.2	0.8		1.4	1.1		1.7	1.3	0.2
		Gas boiler							0.2			0.4	0.1		0.7	0.3		1.0	0.6		1.3	0.9		1.5	1.2	0.0	1.8	1.4	0.3	2.1	1.7	0.6	2.4	2.0	0.8
End Terrace House	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																								0.0			0.2						
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler										0.0			0.2			0.4	0.1		0.6	0.3		0.8	0.5		0.9	0.6		1.1	0.8				
	Individual options	**GSHP**	0.0			0.2			0.4			0.5			0.7	0.0		0.9	0.2	0.1	1.1	0.4	0.3	1.3	0.6	0.4	1.4	0.7	0.6	1.6	0.9	0.8			
		ASHP + SHW							0.0			0.2			0.4	0.1		0.5	0.3		0.7	0.5		0.9	0.7		1.1	0.9		1.3	1.0	0.2			
		ASHP	0.5	0.3		0.7	0.4		0.9	0.6		1.0	0.8		1.2	1.0	0.1	1.4	1.2	0.3	1.6	1.3	0.5	1.7	1.5	0.6	1.9	1.7	0.8	2.1	1.9	1.0			
		Direct Elec	3.4	2.8	0.4	3.5	3.0	0.5	3.7	3.2	0.7	3.9	3.3	0.9	4.1	3.5	1.1	4.2	3.7	1.2	4.4	3.9	1.4	4.6	4.1	1.6	4.8	4.2	1.8	5.0	4.4	2.0			
		Gas boiler + SHW							0.0			0.2			0.4	0.1		0.6	0.3		0.7	0.5		0.9	0.7		1.1	0.8		1.3	1.0	0.1			
		Gas boiler	0.3	0.0		0.4	0.2		0.6	0.4		0.8	0.6		1.0	0.7		1.2	0.9		1.3	1.1	0.1	1.5	1.3	0.3	1.7	1.4	0.5	1.9	1.6	0.7			
Mid Terrace House	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																			0.2			0.3	0.2		0.5	0.3		0.7	0.5				
	Individual options	**GSHP**							0.1			0.3			0.5			0.6			0.8	0.2	0.1	1.0	0.4	0.3	1.2	0.5	0.5	1.4	0.7	0.7			
		ASHP + SHW													0.0			0.2	0.1		0.4	0.2		0.6	0.4		0.7	0.6		0.9	0.8				
		ASHP	0.2	0.0		0.3	0.2		0.5	0.4		0.7	0.5		0.9	0.7		1.1	0.9	0.1	1.2	1.1	0.3	1.4	1.3	0.5	1.6	1.4	0.7	1.8	1.6	0.8			
		Direct Elec	2.5	2.2		2.7	2.4	0.1	2.9	2.5	0.3	3.1	2.7	0.5	3.3	2.9	0.6	3.4	3.1	0.8	3.6	3.2	1.0	3.8	3.4	1.2	4.0	3.6	1.4	4.2	3.8	1.5			
		Gas boiler + SHW													0.0			0.2	0.0		0.4	0.2		0.6	0.4		0.7	0.6		0.9	0.7				
		Gas boiler				0.1			0.3	0.1		0.4	0.3		0.6	0.5		0.8	0.6		1.0	0.8		1.2	1.0	0.1	1.3	1.2	0.3	1.5	1.3	0.5			
3-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																			1														
	Individual options	**ASHP + SHW**										3			6	2		9	5		12	8													
		ASHP	10	6		13	9		16	12		19	15	3	22	18	6	25	21	9	28	24	12											
		Direct Elec	48	39	3	51	42	6	54	45	9	57	48	12	60	51	15	63	54	19	66	57	22												
		Gas boiler + SHW										2			5	1		8	4		11	7													
		Gas boiler	4			7	3		10	6		13	9		16	12		19	15	1	22	18	4											
4-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																																	
	Individual options	**ASHP + SHW**										2			6	2		10	6		14	10													
		ASHP	11	7		16	11		20	15		24	19	3	28	23	7	32	27	11	36	31	15											
		Direct Elec	59	48	2	63	52	6	67	56	10	71	60	14	76	64	18	80	68	22	84	73	26												
		Gas boiler + SHW										0			4			8	3		12	7													
		Gas boiler	3			7	2		11	6		15	10		19	14		23	18	1	27	22	5											
8-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																						1			9			17	7		25	16	
	Individual options	**ASHP**	19	10		27	18		35	26		43	35	3	51	43	11	60	51	19	68	59	27	76	67	36	84	75	44	92	84	52	100	92	60
		Direct Elec	105	85		113	93	4	121	102	12	129	110	20	138	118	28	146	126	37	154	134	45	162	142	53	170	151	61	178	159	69	187	167	77
		Gas boiler				8			16	7		24	16		33	24		41	32		49	40	6	57	48	14	65	56	23	73	65	31	82	73	39
20-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																								12			33	10		53	30		
	Individual options	**ASHP**	40	20		61	41		81	61		102	81	3	122	102	24	142	122	44	163	143	65	183	163	85	204	184	106	224	204	126	245	225	147
		Direct Elec	242	197		262	217		283	238	18	303	258	39	324	279	59	344	299	80	365	320	100	385	340	121	406	361	141	426	381	162	446	401	182
		Gas boiler				11			32	11		52	32		72	52		93	73		113	93	11	134	114	31	154	134	52	175	154	72	195	175	93
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

Key	Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = kWp PV required

* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

CC4TNH 2013 CO2 emission factors

Carbon emissions

$kgCO_{2(eq)}/m^2/yr$			20			19			18			17			16			15			14			13			12			11			10		
Detached House	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																									0.1			0.3			0.5	0.1	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																		0.2			0.4	0.0		0.6	0.3		0.9	0.5		1.1	0.7	
	Individual options	**GSHP**	0.1			0.3	0.0		0.5	0.3		0.8	0.5		1.0	0.7		1.2	0.9	0.2	1.4	1.2	0.4	1.7	1.4	0.7	1.9	1.6	0.9	2.1	1.9	1.1	2.4	2.1	1.3
		ASHP + SHW				0.1			0.3			0.5	0.2		0.8	0.4		1.0	0.6		1.2	0.9		1.5	1.1	0.0	1.7	1.3	0.3	1.9	1.6	0.5	2.1	1.8	0.7
		ASHP	0.8	0.4		1.0	0.7		1.2	0.9		1.5	1.1	0.1	1.7	1.4	0.3	1.9	1.6	0.5	2.2	1.8	0.8	2.4	2.0	1.0	2.6	2.3	1.2	2.8	2.5	1.4	3.1	2.7	1.7
		Direct Elec	5.1	4.2	1.2	5.3	4.4	1.5	5.5	4.7	1.7	5.7	4.9	1.9	6.0	5.1	2.1	6.2	5.4	2.4	6.4	5.6	2.6	6.6	5.8	2.8	6.9	6.0	3.0	7.1	6.3	3.3	7.3	6.5	3.5
		Gas boiler + SHW													0.2			0.4	0.1		0.7	0.3		0.9	0.6		1.1	0.8		1.3	1.0	0.1	1.6	1.2	0.3
		Gas boiler				0.0			0.3			0.5	0.2		0.7	0.4		0.9	0.6		1.2	0.9		1.4	1.1	0.2	1.6	1.3	0.4	1.9	1.5	0.7	2.1	1.8	0.9
End Terrace House	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																												0.1					
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																0.0			0.2			0.3	0.1		0.5	0.2		0.6	0.4				
	Individual options	**GSHP**	0.6			0.8	0.1		0.9	0.2	0.1	1.1	0.4	0.3	1.2	0.5	0.4	1.4	0.7	0.6	1.5	0.8	0.7	1.7	1.0	0.9	1.8	1.1	1.0	2.0	1.3	1.2			
		ASHP + SHW	0.3	0.1		0.4	0.2		0.6	0.4		0.7	0.5		0.9	0.6		1.0	0.8		1.2	0.9	0.1	1.3	1.1	0.2	1.5	1.2	0.4	1.6	1.4	0.5			
		ASHP	1.1	0.9	0.0	1.3	1.1	0.2	1.4	1.2	0.3	1.6	1.3	0.5	1.7	1.5	0.6	1.9	1.6	0.8	2.0	1.8	0.9	2.2	1.9	1.1	2.3	2.1	1.2	2.5	2.2	1.4			
		Direct Elec	4.0	3.4	1.0	4.1	3.6	1.1	4.3	3.7	1.3	4.4	3.9	1.4	4.6	4.0	1.6	4.7	4.2	1.7	4.9	4.3	1.9	5.0	4.5	2.0	5.2	4.6	2.2	5.3	4.8	2.3			
		Gas boiler + SHW				0.0			0.2			0.3	0.1		0.4	0.2		0.6	0.4		0.7	0.5		0.9	0.7		1.0	0.8	0.1	1.2	1.0	0.2			
		Gas boiler	0.3	0.1		0.5	0.3		0.6	0.4		0.8	0.6		0.9	0.7		1.1	0.9	0.1	1.2	1.0	0.3	1.4	1.2	0.4	1.5	1.3	0.6	1.7	1.4	0.7			
Mid Terrace House	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																									0.1			0.3	0.1				
	Individual options	**GSHP**	0.4			0.5			0.7	0.0	0.0	0.8	0.2	0.2	1.0	0.3	0.3	1.1	0.5	0.4	1.3	0.6	0.6	1.4	0.8	0.7	1.6	0.9	0.9	1.7	1.1	1.0			
		ASHP + SHW				0.1			0.3	0.1		0.4	0.2		0.5	0.4		0.7	0.5		0.8	0.7		1.0	0.8	0.0	1.1	1.0	0.2	1.3	1.1	0.3			
		ASHP	0.8	0.6		0.9	0.8	0.0	1.1	0.9	0.2	1.2	1.1	0.3	1.4	1.2	0.5	1.5	1.4	0.6	1.7	1.5	0.8	1.8	1.7	0.9	2.0	1.8	1.0	2.1	2.0	1.2			
		Direct Elec	3.2	2.8	0.6	3.3	3.0	0.7	3.5	3.1	0.9	3.6	3.3	1.0	3.8	3.4	1.2	3.9	3.5	1.3	4.1	3.7	1.4	4.2	3.8	1.6	4.4	4.0	1.7	4.5	4.1	1.9			
		Gas boiler + SHW										0.0			0.2	0.0		0.3	0.2		0.4	0.3		0.6	0.5		0.7	0.6		0.9	0.7	0.1			
		Gas boiler	0.0			0.2	0.0		0.3	0.2		0.5	0.3		0.6	0.5		0.8	0.6		0.9	0.8	0.1	1.1	0.9	0.3	1.2	1.1	0.4	1.4	1.2	0.6			
3-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																																	
	Individual options	**ASHP + SHW**	5	1		7	3		10	6		12	9		15	11		17	14	1	20	16	4												
		ASHP	21	17	4	23	19	7	26	22	9	28	24	12	31	27	15	33	29	17	36	32	20												
		Direct Elec	59	50	14	61	52	17	64	55	19	66	57	22	69	60	24	71	62	27	74	65	29												
		Gas boiler + SHW							1			4	1		6	3		9	6		11	8													
		Gas boiler	5	2		8	5		10	7		13	10		15	12	1	18	15	4	20	17	6												
4-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																																	
	Individual options	**ASHP + SHW**	4			8	3		11	7		14	10		18	13		21	17	1	25	20	4												
		ASHP	26	21	5	29	25	8	33	28	12	36	31	15	40	35	19	43	38	22	46	41	25												
		Direct Elec	74	63	16	77	66	20	81	69	23	84	73	26	87	76	30	91	79	33	94	83	36												
		Gas boiler + SHW							0			4			7	3		10	6		14	10													
		Gas boiler	5	1		9	5		12	8		15	11		19	15	1	22	18	4	26	21	8												
8-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																															4		
	Individual options	**ASHP**	48	39	8	55	46	14	61	53	21	68	59	28	75	66	34	81	73	41	88	80	48	95	86	55	102	93	61	108	100	68	115	106	75
		Direct Elec	134	115	25	141	121	32	148	128	38	154	135	45	161	141	52	168	148	58	174	155	65	181	162	72	188	168	79	195	175	85	201	182	92
		Gas boiler	6			13	5		19	12		26	19		33	26		39	32	6	46	39	13	53	46	20	60	52	26	66	59	33	73	66	40
20-Storey Apartment Block	**Communal options**	**Biomass boiler**																																	
		Biomass CHP + Gas boiler																																	
		Gas CHP + Biomass boiler																																	
		Gas CHP + Gas boiler																															1		
	Individual options	**ASHP**	113	93	15	130	110	32	147	127	49	164	144	66	181	160	82	197	177	99	214	194	116	231	211	133	248	228	150	265	244	166	281	261	183
		Direct Elec	315	270	50	332	287	67	349	304	84	366	321	101	382	337	118	399	354	134	416	371	151	433	388	168	450	404	185	466	421	202	483	438	218
		Gas boiler	7			24	8		41	24		58	41		74	58		91	75	11	108	92	28	125	108	45	142	125	62	158	142	79	175	159	95
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

Key	Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = kWp PV required

* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

DECC 2013 CO2 emission factors

Carbon emissions

$kgCO_{2(eq)}/m^2/yr$

			20			19			18			17			16			15			14			13			12			11			10		
Detached House	Communal options	Biomass boiler																																
		Biomass CHP + Gas boiler																														0.4		
		Gas CHP + Biomass boiler																																
		Gas CHP + Gas boiler																		0.3			0.7	0.2		1.0	0.5		1.4	0.9		1.8	1.3	
	Individual options	GSHP																							0.2			0.6	0.3		0.9	0.7	
		ASHP + SHW																										0.3			0.7	0.4	
		ASHP																		0.2			0.5	0.2		0.9	0.5		1.3	0.9		1.6	1.3	0.2
		Direct Elec	2.2	1.4		2.6	1.7		2.9	2.1		3.3	2.5		3.7	2.8		4.0	3.2	0.2	4.4	3.6	0.6	4.8	3.9	1.0	5.2	4.3	1.3	5.5	4.7	1.7	5.9	5.1	2.1
		Gas boiler + SHW																						0.3			0.6	0.2		1.0	0.6		1.4	0.9	
		Gas boiler																0.3			0.7	0.2		1.1	0.6		1.4	1.0		1.8	1.4		2.2	1.7	0.3
End Terrace House	Communal options	Biomass boiler																																
		Biomass CHP + Gas boiler																																
		Gas CHP + Biomass boiler																																
		Gas CHP + Gas boiler													0.0			0.3			0.5	0.2		0.8	0.4		1.0	0.7		1.2	0.9				
	Individual options	GSHP																			0.2			0.5			0.7	0.0		1.0	0.2	0.1		
		ASHP + SHW																						0.1			0.4	0.1		0.6	0.4				
		ASHP										0.0			0.2	0.0		0.5	0.3		0.7	0.5		1.0	0.7		1.2	0.9		1.4	1.2	0.3			
		Direct Elec	2.1	1.6		2.4	1.8		2.6	2.1		2.9	2.3		3.1	2.5	0.1	3.3	2.8	0.3	3.6	3.0	0.6	3.8	3.3	0.8	4.1	3.5	1.1	4.3	3.7	1.3			
		Gas boiler + SHW																0.1			0.3	0.0		0.6	0.3		0.8	0.5		1.0	0.7				
		Gas boiler							0.1			0.3	0.0		0.5	0.3		0.8	0.5		1.0	0.7		1.3	1.0		1.5	1.2	0.1	1.7	1.5	0.3			
Mid Terrace House	Communal options	Biomass boiler																																
		Biomass CHP + Gas boiler																																
		Gas CHP + Biomass boiler																																
		Gas CHP + Gas boiler																			0.0			0.3	0.0		0.5	0.3		0.7	0.5				
	Individual options	GSHP																						0.2			0.5			0.7	0.0	0.0			
		ASHP + SHW																									0.0			0.3	0.1				
		ASHP																0.1			0.4	0.2		0.6	0.5		0.9	0.7		1.1	1.0	0.2			
		Direct Elec	1.3	1.0		1.6	1.2		1.8	1.4		2.1	1.7		2.3	1.9		2.5	2.2		2.8	2.4	0.2	3.0	2.6	0.4	3.2	2.9	0.6	3.5	3.1	0.9			
		Gas boiler + SHW																						0.1			0.4	0.2		0.6	0.4				
		Gas boiler													0.1			0.4	0.2		0.6	0.4		0.8	0.6		1.1	0.9		1.3	1.1	0.1			
3-Storey Apartment Block	Communal options	Biomass boiler																																
		Biomass CHP + Gas boiler																																
		Gas CHP + Biomass boiler																																
		Gas CHP + Gas boiler																			1													
	Individual options	ASHP + SHW																																
		ASHP										1			5	2		9	6		14	10												
		Direct Elec	27	18		31	22		35	26		39	30		43	34		48	38	3	52	43	7										
		Gas boiler + SHW																			3													
		Gas boiler										4			8	3		12	8		16	12												
4-Storey Apartment Block	Communal options	Biomass boiler																																
		Biomass CHP + Gas boiler																																
		Gas CHP + Biomass boiler																																
		Gas CHP + Gas boiler																																
	Individual options	ASHP + SHW																																
		ASHP										0			6	1		11	6		17	12												
		Direct Elec	32	20		37	26		42	31		48	37		53	42		59	48	1	64	53	7										
		Gas boiler + SHW																			1													
		Gas boiler										3			9	3		14	8		19	14												
8-Storey Apartment Block	Communal options	Biomass boiler																																
		Biomass CHP + Gas boiler																																
		Gas CHP + Biomass boiler																																
		Gas CHP + Gas boiler																									10			21	9		32	20	
	Individual options	ASHP													7			18	9		29	20		40	31		51	42	11	62	53	22	73	64	32
		Direct Elec	50	30		61	41		71	52		82	63		93	74		104	85		115	96	6	126	107	17	137	118	28	148	128	39	159	139	50
		Gas boiler													10			21	11		32	22		43	33		54	44	2	65	54	13	76	65	24
20-Storey Apartment Block	Communal options	Biomass boiler																																
		Biomass CHP + Gas boiler																																
		Gas CHP + Biomass boiler																																
		Gas CHP + Gas boiler																									12			40	13		67	40	
	Individual options	ASHP													11			39	19		66	46		93	73		121	101	23	148	128	50	176	155	77
		Direct Elec	104	59		131	86		159	113		186	141		213	168		241	196		268	223	3	295	250	31	323	278	58	350	305	85	377	332	113
		Gas boiler													14			42	18		69	46		96	73		124	100	1	151	128	28	179	155	55
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

Key	Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = kWp PV required

* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

CC4TNH 2016 CO2 emission factors

Carbon emissions reduction (from 2006 Part L) - NOTE UNEVEN SCALE

Emissions Reduction			25%			28%			31%			34%			37%			40%			42%			44%			48%			52%			56%			60%		
Detached House	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																														0.1			0.4		
		Gas CHP + Biomass boiler																																			
		Gas CHP + Gas boiler																		0.1			0.3			0.6	0.1		0.9	0.4		1.2	0.7		1.5	1.0	
	Individual options	GSHP																0.1			0.3			0.4	0.1		0.7	0.4		1.0	0.7	0.0	1.3	1.0	0.3	1.6	1.3	0.6
		ASHP + SHW																		0.0			0.2			0.5	0.1		0.8	0.4		1.1	0.7		1.4	1.0	
		ASHP							0.2			0.4	0.0		0.6	0.3		0.8	0.5		1.0	0.6		1.1	0.8		1.4	1.1	0.0	1.7	1.4	0.3	2.0	1.7	0.6	2.3	2.0	0.9
		Direct Elec	4.0	3.1	0.1	4.2	3.4	0.4	4.4	3.6	0.6	4.6	3.8	0.8	4.9	4.0	1.0	5.1	4.3	1.3	5.2	4.4	1.4	5.4	4.6	1.6	5.7	4.9	1.9	6.0	5.2	2.2	6.3	5.5	2.5	6.6	5.8	2.8
		Gas boiler + SHW																		0.1			0.3			0.6	0.2		0.9	0.5		1.2	0.8		1.5	1.1	
		Gas boiler										0.2			0.4	0.0		0.6	0.3		0.8	0.4		0.9	0.6		1.2	0.9		1.5	1.2		1.8	1.5	0.3	2.1	1.8	0.6
End Terrace House	Communal options	Biomass boiler																					0.1			0.2			0.4	0.1		0.6	0.3		0.8	0.5	
		Biomass CHP + Gas boiler																																			
		Gas CHP + Biomass boiler																																			
		Gas CHP + Gas boiler																																			
	Individual options	GSHP							0.0			0.2			0.3			0.5			0.6			0.7			0.9	0.2	0.1	1.1	0.4	0.3	1.3	0.6	0.5			
		ASHP + SHW																0.1			0.2			0.3	0.1		0.5	0.3		0.8	0.5		1.0	0.7				
		ASHP	0.2			0.4	0.1		0.5	0.3		0.7	0.4		0.8	0.6		1.0	0.7		1.1	0.8		1.2	0.9	0.1	1.4	1.2	0.3	1.6	1.4	0.5	1.8	1.6	0.7			
		Direct Elec	3.1	2.5	0.1	3.2	2.7	0.2	3.4	2.8	0.4	3.5	3.0	0.5	3.7	3.1	0.7	3.8	3.3	0.8	3.9	3.4	0.9	4.0	3.5	1.0	4.2	3.7	1.2	4.4	3.9	1.4	4.7	4.1	1.7			
		Gas boiler + SHW																0.1			0.2			0.4	0.1		0.6	0.3		0.8	0.5		1.0	0.7				
		Gas boiler				0.1			0.3	0.0		0.4	0.2		0.6	0.3		0.7	0.5		0.8	0.6		0.9	0.7		1.2	0.9		1.4	1.1	0.2	1.6	1.3	0.4			
Mid Terrace House	Communal options	Biomass boiler																																			
		Biomass CHP + Gas boiler																																			
		Gas CHP + Biomass boiler																																			
		Gas CHP + Gas boiler																					0.1			0.2	0.1		0.4	0.3		0.6	0.4				
	Individual options	GSHP							0.1			0.3			0.4			0.5			0.6			0.7	0.1	0.1	0.9	0.3	0.2	1.1	0.5	0.4	1.3	0.6	0.6			
		ASHP + SHW																0.1			0.2	0.1		0.3	0.1		0.5	0.3		0.7	0.5		0.9	0.7				
		ASHP	0.3	0.1		0.4	0.3		0.5	0.4		0.7	0.5		0.8	0.7		1.0	0.8	0.0	1.1	0.9	0.1	1.1	1.0	0.2	1.3	1.2	0.4	1.5	1.4	0.6	1.7	1.5	0.8			
		Direct Elec	2.6	2.3	0.0	2.8	2.4	0.2	2.9	2.6	0.3	3.1	2.7	0.4	3.2	2.8	0.6	3.3	3.0	0.7	3.4	3.1	0.8	3.5	3.2	0.9	3.7	3.3	1.1	3.9	3.5	1.3	4.1	3.7	1.5			
		Gas boiler + SHW																0.1			0.2	0.0		0.3	0.1		0.5	0.3		0.7	0.5		0.8	0.7				
		Gas boiler	0.0			0.1			0.3	0.1		0.4	0.3		0.6	0.4		0.7	0.5		0.8	0.6		0.9	0.7		1.1	0.9	0.1	1.3	1.1	0.2	1.4	1.3	0.4			
3-Storey Apartment Block	Communal options	Biomass boiler																																			
		Biomass CHP + Gas boiler																																			
		Gas CHP + Biomass boiler																																			
		Gas CHP + Gas boiler																																			
	Individual options	ASHP + SHW													1			3			5	1		7	3													
		ASHP	7	3		9	5		12	8		14	11		17	13	1	19	16	3	21	17	5	23	19	7											
		Direct Elec	45	36	0	47	38	3	50	41	5	52	43	8	55	46	10	58	49	13	59	50	15	61	52	16											
		Gas boiler + SHW																2			4			6	2													
		Gas boiler	1			3			6	2		8	4		11	7		14	9		15	11		17	13													
4-Storey Apartment Block	Communal options	Biomass boiler																																			
		Biomass CHP + Gas boiler																																			
		Gas CHP + Biomass boiler																																			
		Gas CHP + Gas boiler																																			
	Individual options	ASHP + SHW													1			4			7	2		9	4													
		ASHP	9	5		13	8		16	11		20	15		23	18	2	26	21	5	28	24	7	31	26	10											
		Direct Elec	57	46		61	49	3	64	53	6	67	56	10	71	59	13	74	63	16	76	65	19	78	67	21											
		Gas boiler + SHW																3			5			7	2													
		Gas boiler	1			4			8	3		11	6		14	9		18	13		20	15		22	17													
8-Storey Apartment Block	Communal options	Biomass boiler																																			
		Biomass CHP + Gas boiler																																			
		Gas CHP + Biomass boiler																																			
		Gas CHP + Gas boiler																											4			13	3		21	11	
	Individual options	ASHP	21	12		27	19		34	25		40	32		47	38	6	53	45	13	57	49	17	62	53	22	70	62	30	79	70	39	88	79	47	96	88	56
		Direct Elec	107	88		114	94	4	120	100	11	127	107	17	133	113	24	139	120	30	144	124	34	148	128	39	157	137	47	165	146	56	174	154	65	182	163	73
		Gas boiler	2			9			15	6		22	13		28	19		34	26		39	30		43	34	0	52	43	9	60	51	18	69	60	26	77	69	35
20-Storey Apartment Block	Communal options	Biomass boiler																																			
		Biomass CHP + Gas boiler																																			
		Gas CHP + Biomass boiler																																			
		Gas CHP + Gas boiler																											6			27	4		48	25	
	Individual options	ASHP	55	35		71	51		87	67		103	83	4	118	98	20	134	114	36	145	125	46	155	135	57	176	156	78	197	177	99	218	198	120	239	219	141
		Direct Elec	257	212		273	228	8	289	244	24	304	259	40	320	275	56	336	291	71	346	301	82	357	312	92	378	333	113	399	354	134	420	375	155	441	396	176
		Gas boiler	6			22	1		37	17		53	33		69	49		85	64		95	75		106	85	3	127	106	24	148	127	45	169	148	66	190	169	87
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

Key			
Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = kWp PV required
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* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

CC4TNH 2013 CO2 emission factors

Carbon emissions reduction (from 2006 Part L) - NOTE UNEVEN SCALE

Emissions Reduction			25%	28%	31%	34%	37%	40%	42%	44%	48%	52%	56%	60%
Detached House	Communal options	Biomass boiler												
		Biomass CHP + Gas boiler											0.0	0.3
		Gas CHP + Biomass boiler												
		Gas CHP + Gas boiler									0.1	0.3	0.6 0.2	0.8 0.5
	Individual options	GSHP		0.1	0.3 0.0	0.5 0.2	0.7 0.4	0.8 0.6	1.0 0.7	1.1 0.8 0.1	1.4 1.1 0.3	1.6 1.3 0.6	1.9 1.6 0.8	2.1 1.8 1.1
		ASHP + SHW			0.1	0.2	0.4 0.1	0.6 0.3	0.7 0.4	0.9 0.5	1.1 0.8	1.4 1.0	1.6 1.3 0.2	1.9 1.5 0.5
		ASHP	0.6 0.3	0.8 0.4	1.0 0.6	1.2 0.8	1.4 1.0	1.6 1.2 0.2	1.7 1.3 0.3	1.8 1.5 0.4	2.1 1.7 0.7	2.3 2.0 0.9	2.6 2.2 1.2	2.8 2.5 1.4
		Direct Elec	4.9 4.0 1.0	5.1 4.2 1.2	5.2 4.4 1.4	5.4 4.6 1.6	5.6 4.8 1.8	5.8 5.0 2.0	5.9 5.1 2.1	6.1 5.2 2.2	6.3 5.5 2.5	6.6 5.7 2.7	6.8 6.0 3.0	7.1 6.2 3.2
		Gas boiler + SHW						0.1	0.2	0.3	0.6 0.2	0.8 0.5	1.1 0.7	1.3 1.0 0.1
		Gas boiler			0.0	0.2	0.4 0.1	0.6 0.3	0.7 0.4	0.8 0.5	1.1 0.8	1.3 1.0 0.1	1.6 1.3 0.4	1.8 1.5 0.6
End Terrace House	Communal options	Biomass boiler												
		Biomass CHP + Gas boiler												
		Gas CHP + Biomass boiler												
		Gas CHP + Gas boiler										0.2	0.3 0.1	
	Individual options	GSHP	0.3	0.5	0.6	0.7 0.0	0.8 0.1 0.0	1.0 0.3 0.2	1.1 0.4 0.2	1.2 0.4 0.3	1.3 0.6 0.5	1.5 0.8 0.7	1.7 1.0 0.9	
		ASHP + SHW		0.1	0.2 0.0	0.4 0.1	0.5 0.3	0.6 0.4	0.7 0.5	0.8 0.6	1.0 0.7	1.1 0.9 0.0	1.3 1.1 0.2	
		ASHP	0.8 0.6	0.9 0.7	1.1 0.8	1.2 1.0 0.1	1.3 1.1 0.2	1.5 1.2 0.4	1.6 1.3 0.5	1.6 1.4 0.5	1.8 1.6 0.7	2.0 1.8 0.9	2.2 1.9 1.1	
		Direct Elec	3.7 3.1 0.7	3.8 3.2 0.8	3.9 3.4 0.9	4.1 3.5 1.1	4.2 3.6 1.2	4.3 3.8 1.3	4.4 3.9 1.4	4.5 3.9 1.5	4.7 4.1 1.7	4.8 4.3 1.8	5.0 4.5 2.0	
		Gas boiler + SHW					0.1	0.2	0.3 0.1	0.4 0.2	0.5 0.3	0.7 0.5	0.9 0.7	
		Gas boiler	0.0	0.1	0.3 0.1	0.4 0.2	0.5 0.3	0.7 0.5	0.7 0.5	0.8 0.6	1.0 0.8 0.1	1.2 1.0 0.2	1.4 1.2 0.4	
Mid Terrace House	Communal options	Biomass boiler												
		Biomass CHP + Gas boiler												
		Gas CHP + Biomass boiler												
		Gas CHP + Gas boiler										0.0	0.2 0.0	
	Individual options	GSHP	0.4	0.5	0.6	0.7 0.1 0.1	0.9 0.2 0.2	1.0 0.3 0.3	1.1 0.4 0.4	1.1 0.5 0.5	1.3 0.7 0.6	1.4 0.8 0.8	1.6 1.0 0.9	
		ASHP + SHW		0.1	0.2 0.0	0.3 0.2	0.4 0.3	0.6 0.4	0.6 0.5	0.7 0.6	0.9 0.7	1.0 0.9 0.1	1.2 1.0 0.2	
		ASHP	0.8 0.7	0.9 0.8 0.0	1.0 0.9 0.1	1.2 1.0 0.2	1.3 1.1 0.4	1.4 1.2 0.5	1.5 1.3 0.5	1.6 1.4 0.6	1.7 1.6 0.8	1.9 1.7 0.9	2.0 1.9 1.1	
		Direct Elec	3.2 2.8 0.6	3.3 2.9 0.7	3.4 3.1 0.8	3.5 3.2 0.9	3.7 3.3 1.0	3.8 3.4 1.2	3.9 3.5 1.2	3.9 3.6 1.3	4.1 3.7 1.5	4.2 3.9 1.6	4.4 4.0 1.8	
		Gas boiler + SHW					0.0	0.2 0.0	0.2 0.1	0.3 0.2	0.5 0.3	0.6 0.5	0.8 0.6	
		Gas boiler	0.0	0.2 0.0	0.3 0.1	0.4 0.3	0.5 0.4	0.6 0.5	0.7 0.6	0.8 0.7	0.9 0.8 0.2	1.1 1.0 0.3	1.3 1.1 0.5	
3-Storey Apartment Block	Communal options	Biomass boiler												
		Biomass CHP + Gas boiler												
		Gas CHP + Biomass boiler												
		Gas CHP + Gas boiler												
	Individual options	ASHP + SHW	1	3	5 1	7 4	9 6	12 8	13 9	15 11				
		ASHP	17 13 1	19 15 3	21 17 5	23 19 7	25 22 9	28 24 11	29 25 13	30 27 14				
		Direct Elec	55 46 10	57 48 12	59 50 15	61 52 17	64 54 19	66 57 21	67 58 23	69 60 24				
		Gas boiler + SHW					1	3 0	5 1	6 3				
		Gas boiler	1	4 0	6 2	8 5	10 7	12 9	14 10	15 12 1				
4-Storey Apartment Block	Communal options	Biomass boiler												
		Biomass CHP + Gas boiler												
		Gas CHP + Biomass boiler												
		Gas CHP + Gas boiler												
	Individual options	ASHP + SHW	1	4	7 2	9 5	12 8	15 10	17 12	19 14				
		ASHP	23 18 2	25 21 4	28 24 7	31 26 10	34 29 13	37 32 16	39 34 18	41 36 20				
		Direct Elec	70 59 13	73 62 16	76 65 18	79 68 21	82 71 24	84 73 27	86 75 29	88 77 31				
		Gas boiler + SHW					1	4 0	6 2	8 4				
		Gas boiler	2	5 1	8 4	10 6	13 9	16 12	18 14 0	20 16 2				
8-Storey Apartment Block	Communal options	Biomass boiler												
		Biomass CHP + Gas boiler												
		Gas CHP + Biomass boiler												
		Gas CHP + Gas boiler												
	Individual options	ASHP	46 38 6	52 43 11	57 48 17	63 54 22	68 59 28	73 65 33	77 68 37	81 72 40	88 79 48	95 87 55	102 94 62	110 101 69
		Direct Elec	132 113 23	138 118 29	143 124 34	149 129 39	154 135 45	160 140 50	163 144 54	167 147 58	174 155 65	181 162 72	189 169 79	196 176 87
		Gas boiler	4	10 2	15 8	21 13	26 19	31 24	35 28 2	39 31 5	46 39 13	53 46 20	60 53 27	68 60 34
20-Storey Apartment Block	Communal options	Biomass boiler												
		Biomass CHP + Gas boiler												
		Gas CHP + Biomass boiler												
		Gas CHP + Gas boiler												
	Individual options	ASHP	117 97 19	130 110 32	143 123 45	157 137 59	170 150 72	183 163 85	192 172 94	201 181 103	219 199 121	236 216 138	254 234 156	272 252 174
		Direct Elec	319 274 54	332 287 67	345 300 81	359 314 94	372 327 107	385 340 120	394 349 129	403 358 138	421 376 156	438 393 174	456 411 191	474 429 209
		Gas boiler	11	24 8	37 21	51 34	64 47	77 61	86 70 6	95 78 15	113 96 33	130 114 51	148 132 68	166 149 86
Fabric specification *			Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C	Int. FEE FEES Spec C

Key					
Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = kWp PV required

* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

DECC 2013 CO2 emission factors

Carbon emissions reduction (from 2006 Part L) - NOTE UNEVEN SCALE

Emissions Reduction			25%			28%			31%			34%			37%			40%			42%			44%			48%			52%			56%			60%		
Detached House	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																													0.3			0.6	0.1	
		Gas CHP + Biomass boiler																																		
		Gas CHP + Gas boiler													0.0			0.3			0.5			0.6	0.1		1.0	0.5		1.3	0.8		1.7	1.2		2.0	1.5	
	Individual options	GSHP																									0.1			0.5	0.2		0.8	0.6		1.2	0.9	0.2
		ASHP + SHW																												0.3			0.6	0.2		0.9	0.6	
		ASHP																0.2			0.3			0.5	0.1		0.8	0.5		1.2	0.8		1.5	1.2	0.1	1.9	1.5	0.5
		Direct Elec	3.1	2.3		3.4	2.5		3.6	2.8		3.9	3.1	0.1	4.2	3.3	0.3	4.4	3.6	0.6	4.6	3.7	0.8	4.8	3.9	0.9	5.1	4.3	1.3	5.4	4.6	1.6	5.8	5.0	2.0	6.1	5.3	2.3
		Gas boiler + SHW																			0.1			0.2			0.6	0.1		0.9	0.5		1.3	0.8		1.6	1.2	
		Gas boiler										0.2			0.4			0.7	0.2		0.9	0.4		1.0	0.6		1.4	0.9		1.7	1.3		2.1	1.6	0.2	2.4	2.0	0.6
End Terrace House	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																																		
		Gas CHP + Biomass boiler																																		
		Gas CHP + Gas boiler													0.1			0.3			0.4	0.1		0.5	0.2		0.8	0.4		1.0	0.7		1.2	0.9				
	Individual options	GSHP																0.0			0.1			0.3			0.5			0.7	0.0		1.0	0.3	0.2			
		ASHP + SHW																									0.1			0.4	0.1		0.6	0.4				
		ASHP										0.2			0.3	0.1		0.5	0.3		0.6	0.4		0.7	0.5		1.0	0.8		1.2	1.0	0.1	1.5	1.2	0.4			
		Direct Elec	2.5	1.9		2.7	2.1		2.8	2.3		3.0	2.5	0.0	3.2	2.6	0.2	3.4	2.8	0.4	3.5	2.9	0.5	3.6	3.1	0.6	3.8	3.3	0.8	4.1	3.5	1.1	4.3	3.8	1.3			
		Gas boiler + SHW																0.1			0.2			0.3	0.0		0.6	0.3		0.8	0.5		1.1	0.8				
		Gas boiler				0.1			0.3			0.5	0.2		0.6	0.3		0.8	0.5		0.9	0.6		1.1	0.8		1.3	1.0		1.5	1.2	0.1	1.8	1.5	0.3			
Mid Terrace House	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																																		
		Gas CHP + Biomass boiler																																		
		Gas CHP + Gas boiler													0.0			0.2			0.3	0.1		0.4	0.2		0.6	0.4		0.8	0.6		1.0	0.8				
	Individual options	GSHP																0.1			0.2			0.3			0.6			0.8	0.1	0.1	1.0	0.3	0.3			
		ASHP + SHW																									0.1			0.3	0.2		0.6	0.4				
		ASHP							0.1			0.2	0.1		0.4	0.2		0.6	0.4		0.7	0.5		0.8	0.6		1.0	0.8	0.1	1.2	1.0	0.3	1.4	1.2	0.5			
		Direct Elec	2.1	1.8		2.3	1.9		2.5	2.1		2.6	2.2		2.8	2.4	0.2	2.9	2.6	0.3	3.0	2.7	0.4	3.1	2.8	0.5	3.4	3.0	0.7	3.6	3.2	1.0	3.8	3.4	1.2			
		Gas boiler + SHW																0.1			0.2			0.3	0.1		0.5	0.3		0.7	0.5		0.9	0.7				
		Gas boiler				0.1			0.3	0.1		0.4	0.3		0.6	0.4		0.8	0.6		0.9	0.7		1.0	0.8		1.2	1.0		1.4	1.2	0.2	1.6	1.4	0.4			
3-Storey Apartment Block	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																																		
		Gas CHP + Biomass boiler																																		
		Gas CHP + Gas boiler																			1			3												
	Individual options	ASHP + SHW																																		
		ASHP				0			3			6	2		9	5		12	8		14	10		16	12												
		Direct Elec	35	26		38	29		41	32		44	35		47	38	2	50	41	5	52	43	7	54	45	9										
		Gas boiler + SHW																1			3			5	0												
		Gas boiler				3			6	1		9	4		12	7		15	10		17	12		19	14												
4-Storey Apartment Block	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																																		
		Gas CHP + Biomass boiler																																		
		Gas CHP + Gas boiler																			0			3												
	Individual options	ASHP + SHW																																		
		ASHP				1			5	0		9	4		13	8		16	12		19	14		21	17	0											
		Direct Elec	45	34		49	38		53	41		56	45		60	49	3	64	53	7	67	55	9	69	58	12										
		Gas boiler + SHW																1			4			6	0												
		Gas boiler				4			8	2		11	6		15	10		19	13		22	16		24	18												
8-Storey Apartment Block	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																																		
		Gas CHP + Biomass boiler																																		
		Gas CHP + Gas boiler																						3			13	1		23	11		33	21		43	31	
	Individual options	ASHP				5			12	4		20	11		27	18		34	26		39	31		44	36	4	54	45	14	64	55	24	74	65	33	84	75	43
		Direct Elec	84	64		91	71		98	79		106	86		113	94	4	121	101	11	125	106	16	130	111	21	140	121	31	150	131	41	160	140	51	170	150	61
		Gas boiler	0			8			15	5		22	12		30	20		37	27		42	32		47	37		57	47	6	67	57	15	77	66	25	86	76	35
20-Storey Apartment Block	Communal options	Biomass boiler																																		
		Biomass CHP + Gas boiler																																		
		Gas CHP + Biomass boiler																																		
		Gas CHP + Gas boiler																						4			28	1		52	25		76	49		100	73	
	Individual options	ASHP				16			34	14		52	32		70	50		88	68		100	80	2	112	92	14	136	116	38	160	140	62	184	164	86	209	188	110
		Direct Elec	200	155		218	173		236	191		254	209		272	227	7	290	245	25	302	257	37	314	269	49	338	293	73	362	317	97	386	341	122	410	365	146
		Gas boiler	1			19			37	14		55	32		73	50		91	68		103	80		115	92		139	116	16	163	140	40	187	164	64	212	188	88
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

Key					
	Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = kWp PV required

* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

Appendix A2

Bar graphs of carbon emissions from fabric and heat technology combinations only (prior to any zero carbon electricity generation).

Heat technologies:

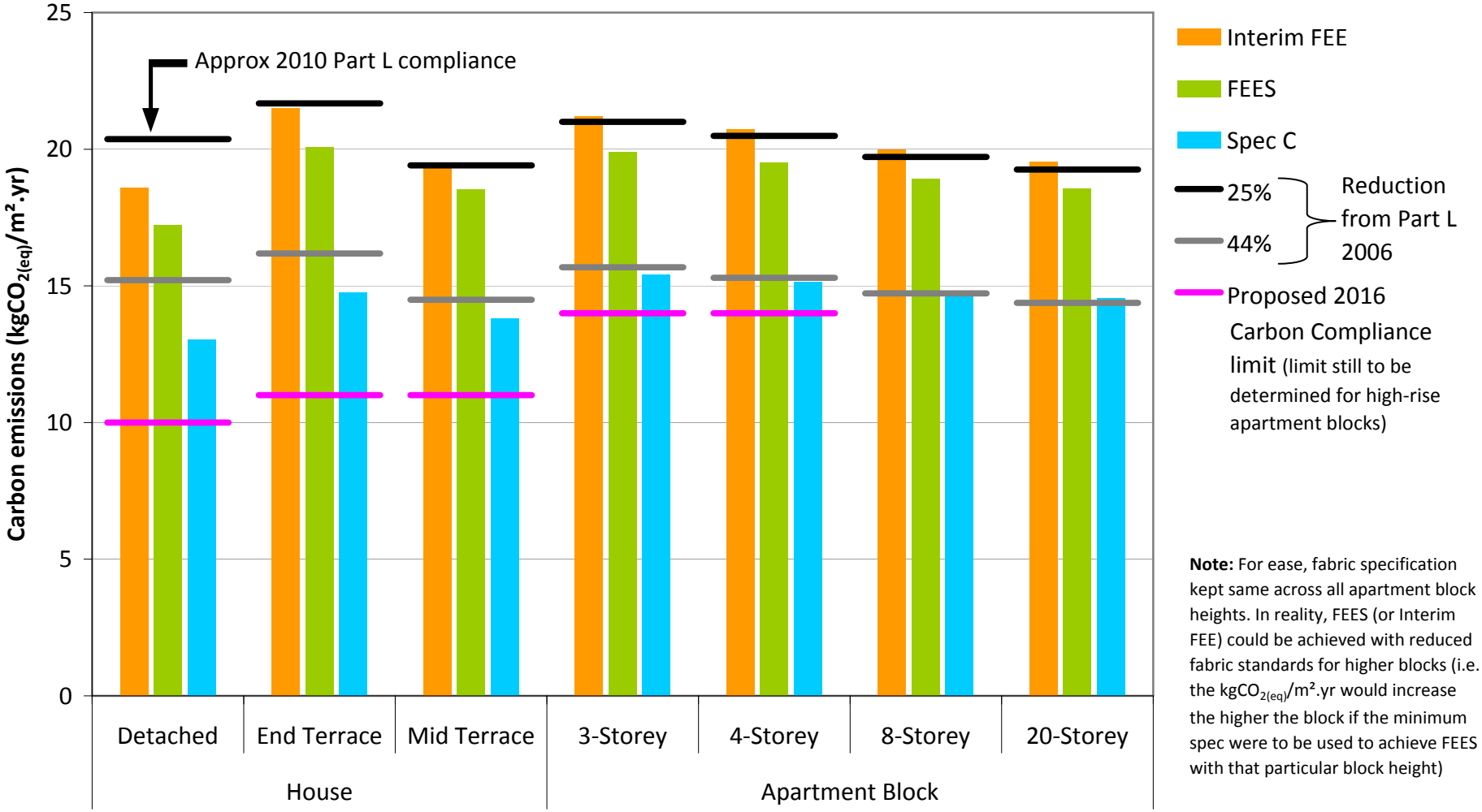
- Gas
- Gas + SHW
- ASHP
- ASHP + SHW
- Gas CHP

Fabric energy efficiency scenarios:

- Interim FEE
- FEES
- Spec C

Carbon comparison: Gas boiler, no PV

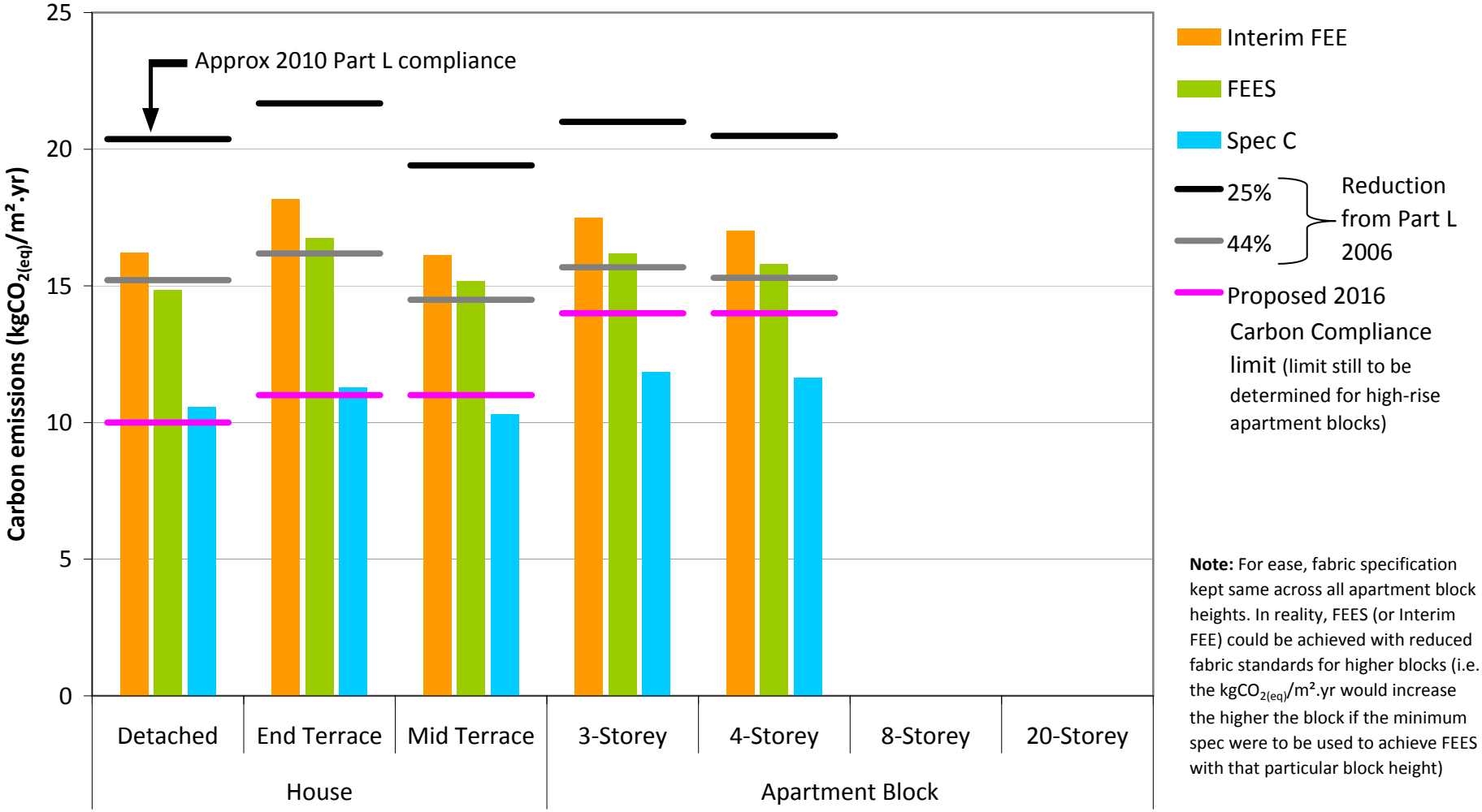
CC4TNH2016 carbon emissions factors, showing three example fabric specifications



Note: For ease, fabric specification kept same across all apartment block heights. In reality, FEES (or Interim FEE) could be achieved with reduced fabric standards for higher blocks (i.e. the $kgCO_{2(eq)}/m^2.yr$ would increase the higher the block if the minimum spec were to be used to achieve FEES with that particular block height)

Carbon comparison: Gas boiler + SHW, no PV

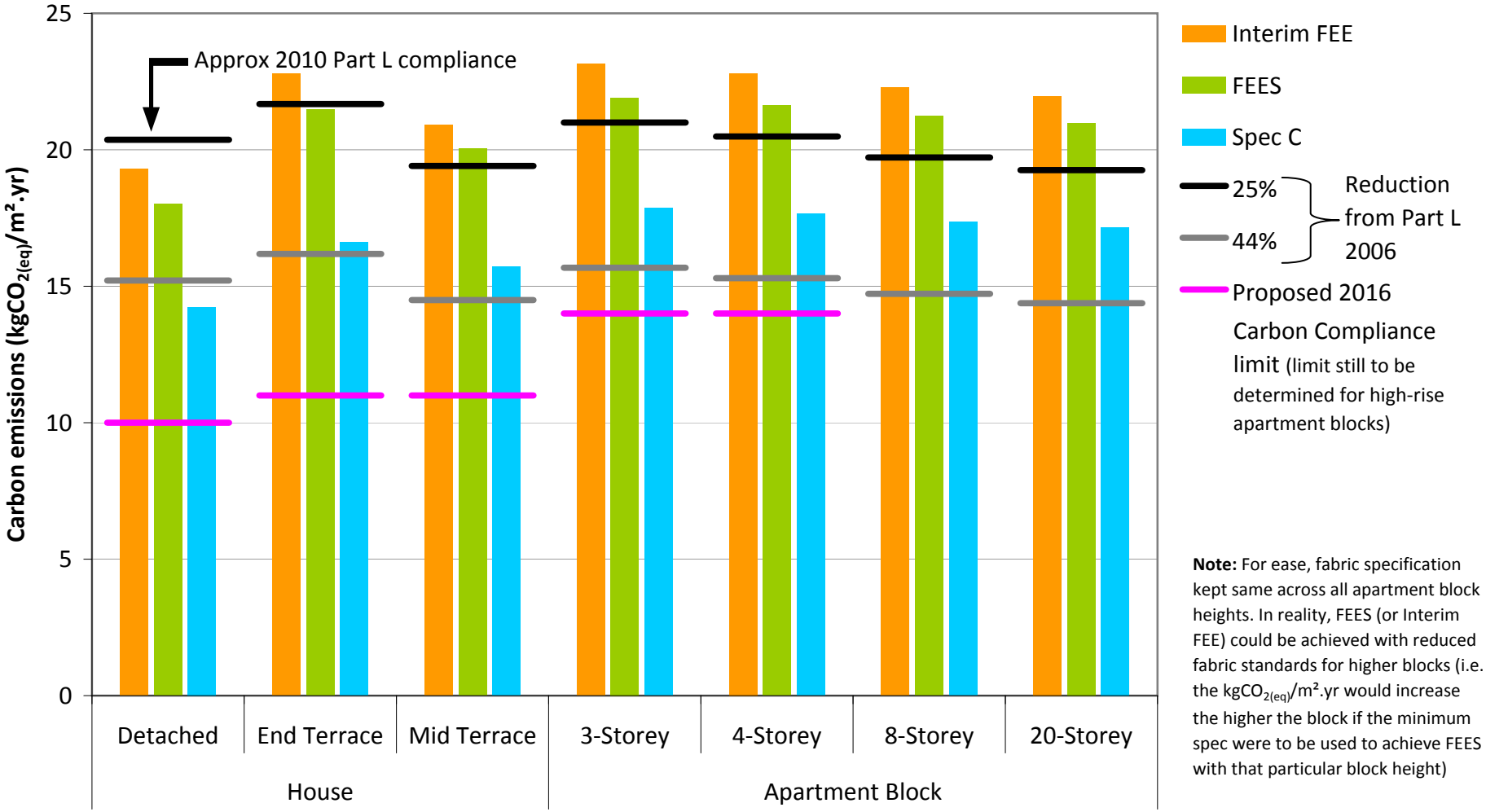
CC4TNH2016 carbon emissions factors, showing three example fabric specifications



Note: For ease, fabric specification kept same across all apartment block heights. In reality, FEES (or Interim FEE) could be achieved with reduced fabric standards for higher blocks (i.e. the $kgCO_{2(eq)}/m^2.yr$ would increase the higher the block if the minimum spec were to be used to achieve FEES with that particular block height)

Carbon comparison: ASHP, no PV

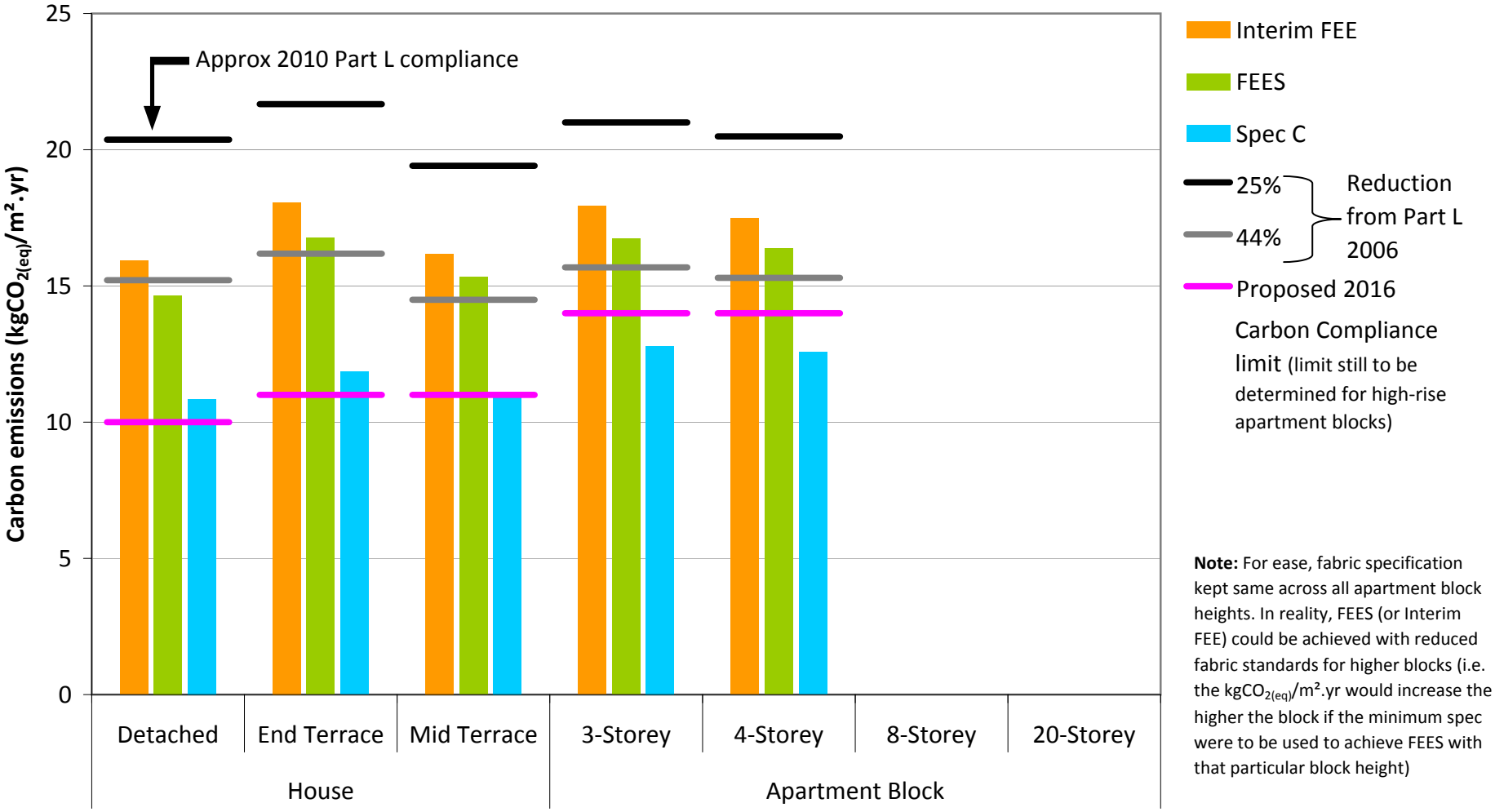
CC4TNH2016 carbon emissions factors, showing three example fabric specifications



Note: For ease, fabric specification kept same across all apartment block heights. In reality, FEES (or Interim FEE) could be achieved with reduced fabric standards for higher blocks (i.e. the $kgCO_{2(eq)}/m^2.yr$ would increase the higher the block if the minimum spec were to be used to achieve FEES with that particular block height)

Carbon comparison: ASHP + SHW, no PV

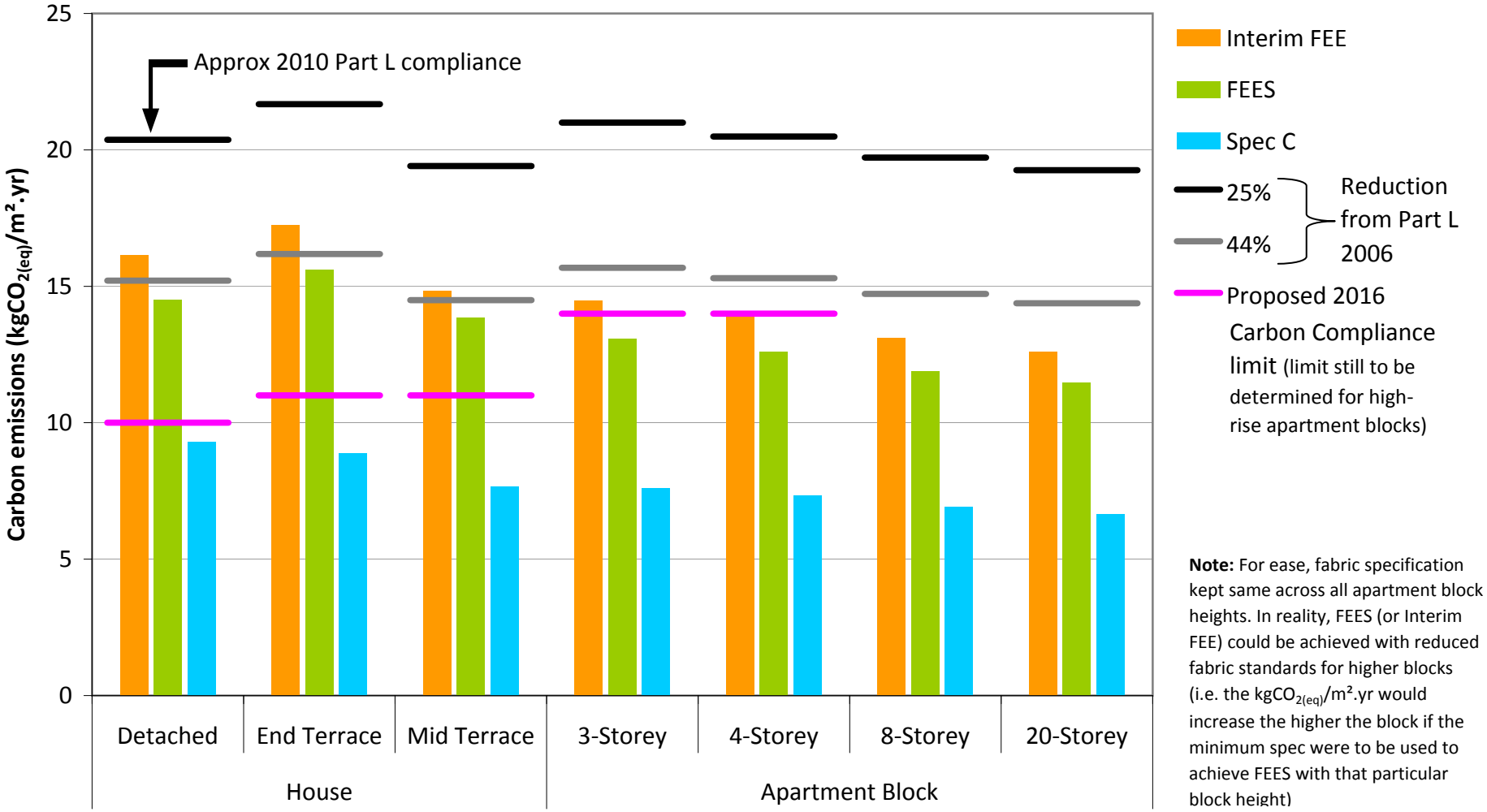
CC4TNH2016 carbon emissions factors, showing three example fabric specifications



Note: For ease, fabric specification kept same across all apartment block heights. In reality, FEES (or Interim FEE) could be achieved with reduced fabric standards for higher blocks (i.e. the $kgCO_{2(eq)}/m^2.yr$ would increase the higher the block if the minimum spec were to be used to achieve FEES with that particular block height)

Carbon comparison: Gas CHP, no PV

CC4TNH2016 carbon emissions factors, showing three example fabric specifications



Note: For ease, fabric specification kept same across all apartment block heights. In reality, FEES (or Interim FEE) could be achieved with reduced fabric standards for higher blocks (i.e. the $kgCO_{2(eq)}/m^2.yr$ would increase the higher the block if the minimum spec were to be used to achieve FEES with that particular block height)

Appendix A3

CO_2 emission factor comparison charts

Impact of different CO_2 emission factors

Carbon emissions

$kgCO_{2(eq)}/m^2/yr$			20			19			18			17			16			15			14			13			12			11			10		
Detached House	Gas boiler	2010 Part L	-1.1	-1.5	-2.5	-0.9	-1.2	-2.2	-0.6	-0.9	-2.0	-0.3	-0.6	-1.7	0.0	-0.4	-1.4	0.2	-0.1	-1.1	0.5	0.2	-0.9	0.8	0.5	-0.6	1.1	0.7	-0.3	1.3	1.0	0.0	1.6	1.3	0.2
		2013 using 2016 methodology	-0.2	-0.5	-1.4	0.0	-0.3	-1.2	0.3	0.0	-0.9	0.5	0.2	-0.7	0.7	0.4	-0.5	0.9	0.6	-0.2	1.2	0.9	0.0	1.4	1.1	0.2	1.6	1.3	0.4	1.9	1.5	0.7	2.1	1.8	0.9
		2013 DECC marginal	-1.5	-2.0	-3.4	-1.2	-1.6	-3.0	-0.8	-1.2	-2.6	-0.4	-0.9	-2.3	-0.1	-0.5	-1.9	0.3	-0.1	-1.5	0.7	0.2	-1.2	1.1	0.6	-0.8	1.4	1.0	-0.4	1.8	1.4	0.0	2.2	1.7	0.3
		Proposed 2016	-0.4	-0.8	-1.9	-0.1	-0.5	-1.6	0.2	-0.2	-1.4	0.4	0.1	-1.1	0.7	0.3	-0.8	1.0	0.6	-0.5	1.3	0.9	-0.3	1.5	1.2	0.0	1.8	1.4	0.3	2.1	1.7	0.6	2.4	2.0	0.8
	ASHP	2010 Part L	-1.5	-1.8	-2.6	-1.3	-1.5	-2.3	-1.0	-1.2	-2.0	-0.7	-1.0	-1.7	-0.4	-0.7	-1.5	-0.2	-0.4	-1.2	0.1	-0.1	-0.9	0.4	0.1	-0.6	0.7	0.4	-0.4	0.9	0.7	-0.1	1.2	1.0	0.2
		2013 using 2016 methodology	0.8	0.4	-0.6	1.0	0.7	-0.4	1.2	0.9	-0.1	1.5	1.1	0.1	1.7	1.4	0.3	1.9	1.6	0.5	2.2	1.8	0.8	2.4	2.0	1.0	2.6	2.3	1.2	2.8	2.5	1.4	3.1	2.7	1.7
		2013 DECC marginal	-2.1	-2.4	-3.5	-1.7	-2.0	-3.1	-1.3	-1.7	-2.7	-1.0	-1.3	-2.3	-0.6	-0.9	-2.0	-0.2	-0.6	-1.6	0.2	-0.2	-1.2	0.5	0.2	-0.9	0.9	0.5	-0.5	1.3	0.9	-0.1	1.6	1.3	0.2
		Proposed 2016	-0.2	-0.5	-1.6	0.1	-0.3	-1.3	0.4	0.0	-1.0	0.6	0.3	-0.8	0.9	0.6	-0.5	1.2	0.8	-0.2	1.5	1.1	0.1	1.7	1.4	0.3	2.0	1.7	0.6	2.3	1.9	0.9	2.6	2.2	1.2
End Terrace House	Gas boiler	2010 Part L	-0.3	-0.5	-1.4	-0.1	-0.3	-1.2	0.1	-0.2	-1.0	0.2	0.0	-0.8	0.4	0.2	-0.7	0.6	0.4	-0.5	0.8	0.5	-0.3	0.9	0.7	-0.1	1.1	0.9	0.0	1.3	1.1	0.2			
		2013 using 2016 methodology	0.3	0.1	-0.6	0.5	0.3	-0.5	0.6	0.4	-0.3	0.8	0.6	-0.2	0.9	0.7	0.0	1.1	0.9	0.1	1.2	1.0	0.3	1.4	1.2	0.4	1.5	1.3	0.6	1.7	1.4	0.7			
		2013 DECC marginal	-0.4	-0.7	-1.8	-0.2	-0.5	-1.6	0.1	-0.2	-1.4	0.3	0.0	-1.1	0.5	0.3	-0.9	0.8	0.5	-0.7	1.0	0.7	-0.4	1.3	1.0	-0.2	1.5	1.2	0.1	1.7	1.5	0.3			
		Proposed 2016	0.3	0.0	-0.9	0.4	0.2	-0.8	0.6	0.4	-0.6	0.8	0.6	-0.4	1.0	0.7	-0.2	1.2	0.9	0.0	1.3	1.1	0.1	1.5	1.3	0.3	1.7	1.4	0.5	1.9	1.6	0.7			
	ASHP	2010 Part L	-0.5	-0.7	-1.4	-0.4	-0.5	-1.2	-0.2	-0.3	-1.0	0.0	-0.2	-0.8	0.2	0.0	-0.6	0.4	0.2	-0.5	0.5	0.4	-0.3	0.7	0.5	-0.1	0.9	0.7	0.1	1.1	0.9	0.3			
		2013 using 2016 methodology	1.1	0.9	0.0	1.3	1.1	0.2	1.4	1.2	0.3	1.6	1.3	0.5	1.7	1.5	0.6	1.9	1.6	0.8	2.0	1.8	0.9	2.2	1.9	1.1	2.3	2.1	1.2	2.5	2.2	1.4			
		2013 DECC marginal	-0.7	-0.9	-1.8	-0.5	-0.7	-1.6	-0.2	-0.5	-1.3	0.0	-0.2	-1.1	0.2	0.0	-0.9	0.5	0.3	-0.6	0.7	0.5	-0.4	1.0	0.7	-0.1	1.2	1.0	0.1	1.4	1.2	0.3			
		Proposed 2016	0.5	0.3	-0.6	0.7	0.4	-0.4	0.9	0.6	-0.2	1.0	0.8	-0.1	1.2	1.0	0.1	1.4	1.2	0.3	1.6	1.3	0.5	1.7	1.5	0.6	1.9	1.7	0.8	2.1	1.9	1.0			
Mid Terrace House	Gas boiler	2010 Part L	-0.6	-0.8	-1.5	-0.4	-0.6	-1.3	-0.3	-0.4	-1.2	-0.1	-0.2	-1.0	0.1	-0.1	-0.8	0.3	0.1	-0.6	0.4	0.3	-0.5	0.6	0.5	-0.3	0.8	0.7	-0.1	1.0	0.8	0.1			
		2013 using 2016 methodology	0.0	-0.1	-0.8	0.2	0.0	-0.6	0.3	0.2	-0.5	0.5	0.3	-0.3	0.6	0.5	-0.2	0.8	0.6	0.0	0.9	0.8	0.1	1.1	0.9	0.3	1.2	1.1	0.4	1.4	1.2	0.6			
		2013 DECC marginal	-0.8	-1.0	-2.0	-0.6	-0.8	-1.8	-0.4	-0.5	-1.6	-0.1	-0.3	-1.3	0.1	-0.1	-1.1	0.4	0.2	-0.9	0.6	0.4	-0.6	0.8	0.6	-0.4	1.1	0.9	-0.1	1.3	1.1	0.1			
		Proposed 2016	-0.1	-0.3	-1.1	0.1	-0.1	-0.9	0.3	0.1	-0.7	0.4	0.3	-0.6	0.6	0.5	-0.4	0.8	0.6	-0.2	1.0	0.8	0.0	1.2	1.0	0.1	1.3	1.2	0.3	1.5	1.3	0.5			
	ASHP	2010 Part L	-0.8	-0.9	-1.5	-0.6	-0.7	-1.3	-0.4	-0.5	-1.1	-0.2	-0.4	-0.9	-0.1	-0.2	-0.8	0.1	0.0	-0.6	0.3	0.2	-0.4	0.5	0.4	-0.2	0.6	0.5	0.0	0.8	0.7	0.1			
		2013 using 2016 methodology	0.8	0.6	-0.1	0.9	0.8	0.0	1.1	0.9	0.2	1.2	1.1	0.3	1.4	1.2	0.5	1.5	1.4	0.6	1.7	1.5	0.8	1.8	1.7	0.9	2.0	1.8	1.0	2.1	2.0	1.2			
		2013 DECC marginal	-1.0	-1.2	-2.0	-0.8	-1.0	-1.7	-0.6	-0.7	-1.5	-0.3	-0.5	-1.3	-0.1	-0.2	-1.0	0.1	0.0	-0.8	0.4	0.2	-0.5	0.6	0.5	-0.3	0.9	0.7	-0.1	1.1	1.0	0.2			
		Proposed 2016	0.2	0.0	-0.8	0.3	0.2	-0.6	0.5	0.4	-0.4	0.7	0.5	-0.2	0.9	0.7	-0.1	1.1	0.9	0.1	1.2	1.1	0.3	1.4	1.3	0.5	1.6	1.4	0.7	1.8	1.6	0.8			
3-Storey Apartment Block	Gas boiler	2010 Part L	-6	-10	-22	-3	-7	-19	0	-4	-16	3	-1	-13	6	3	-10	9	6	-7	12	9	-4												
		2013 using 2016 methodology	5	2	-9	8	5	-6	10	7	-4	13	10	-1	15	12	1	18	15	4	20	17	6												
		2013 DECC marginal	-8	-13	-30	-4	-9	-26	0	-5	-21	4	-1	-17	8	3	-13	12	8	-9	16	12	-5												
		Proposed 2016	4	0	-14	7	3	-11	10	6	-8	13	9	-5	16	12	-2	19	15	1	22	18	4												
	ASHP	2010 Part L	-8	-11	-20	-5	-8	-17	-2	-5	-14	1	-2	-11	4	1	-8	7	4	-5	10	7	-2												
		2013 using 2016 methodology	21	17	4	23	19	7	26	22	9	28	24	12	31	27	15	33	29	17	36	32	20												
		2013 DECC marginal	-11	-15	-27	-7	-11	-23	-3	-7	-19	1	-3	-15	5	2	-11	9	6	-7	14	10	-3												
		Proposed 2016	10	6	-7	13	9	-3	16	12	0	19	15	3	22	18	6	25	21	9	28	24	12												
4-Storey Apartment Block	Gas boiler	2010 Part L	-10	-14	-30	-6	-10	-26	-2	-6	-22	2	-2	-18	6	2	-14	10	6	-10	14	10	-6												
		2013 using 2016 methodology	5	1	-12	9	5	-9	12	8	-6	15	11	-2	19	15	1	22	18	4	26	21	8												
		2013 DECC marginal	-13	-19	-41	-8	-14	-35	-2	-8	-30	3	-3	-24	9	3	-19	14	8	-13	19	14	-8												
		Proposed 2016	3	-2	-20	7	2	-16	11	6	-12	15	10	-8	19	14	-3	23	18	1	27	22	5												
	ASHP	2010 Part L	-12	-16	-28	-8	-12	-24	-4	-7	-20	0	-3	-15	4	1	-11	8	5	-7	12	9	-3												
		2013 using 2016 methodology	26	21	5	29	25	8	33	28	12	36	31	15	40	35	19	43	38	22	46	41	25												
		2013 DECC marginal	-16	-21	-37	-11	-15	-32	-5	-10	-26	0	-5	-21	6	1	-15	11	6	-10	17	12	-4												
		Proposed 2016	11	7	-10	16	11	-5	20	15	-1	24	19	3	28	23	7	32	27	11	36	31	15												
8-Storey Apartment Block	Gas boiler	2010 Part L	-25	-33	-63	-17	-25	-55	-9	-16	-47	-1	-8	-39	7	0	-31	16	8	-23	24	16	-14	32	24	-6	40	32	2	48	41	10	56	49	18
		2013 using 2016 methodology	6	-1	-27	13	5	-21	19	12	-14	26	19	-7	33	26	-1	39	32	6	46	39	13	53	46	20	60	52	26	66	59	33	73	66	40
		2013 DECC marginal	-34	-44	-85	-23	-33	-74	-12	-22	-63	-1	-11	-52	10	0	-41	21	11	-30	32	22	-19	43	33	-9	54	44	2	65	54	13	76	65	24
		Proposed 2016	0	-9	-43	8	-1	-35	16	7	-26	24	16	-18	33	24	-10	41	32	-2	49	40	6	57	48	14	65	56	23	73	65	31	82	73	39
	ASHP	2010 Part L	-27	-34	-57	-19	-26	-49	-11	-17	-41	-3	-9	-33	5	-1	-25	13	7	-17	22	15	-8	30	23	0	38	31	8	46	40	16	54	48	24
		2013 using 2016 methodology	48	39	8	55	46	14	61	53	21	68	59	28	75	66	34	81	73	41	88	80	48	95	86	55	102	93	61	108	100	68	115	106	75
		2013 DECC marginal	-37	-45	-77	-26	-34	-66	-15	-23	-55	-4	-12	-44	7	-1	-33	18	9	-22	29	20	-11	40	31	0	51	42	11	62	53	22	73	64	32
		Proposed 2016	19	10	-22	27	18	-13	35	26	-5	43	35	3	51	43	11	60	51	19	68	59	27	76	67	36	84	75	44	92	84	52	100	92	60
20-Storey Apartment Block	Gas boiler	2010 Part L	-71	-88	-163	-50	-68	-142	-30	-47	-122	-10	-27	-101	11	-7	-81	31	14	-61	51	34	-40	72	54	-20	92	75	0	113	95	21	133	116	41
		2013 using 2016 methodology	7	-9	-73	24	8	-56	41	24	-39	58	41	-22	74	58	-5	91	75	11	108	92	28	125	108	45	142	125	62	158	142	79	175	159	95
		2013 DECC marginal	-95	-118	-218	-68	-91	-191	-40	-64	-164	-13	-36	-136	14	-9	-109	42	18	-81	69	46	-54	96	73	-27	124	100	1	151	128	28	179	155	55
		Proposed 2016	-9	-30	-112	11	-9	-91	32	11	-71	52	32	-50	72	52	-30	93	73	-10	113	93	11	134	114	31	154	134	52	175	154	72	195	175	93
	ASHP	2010 Part L	-73	-88	-146	-53	-68	-126	-32	-47	-105	-12	-27	-85	8	-6	-65	29	14	-44	49	34	-24	70	55	-4	90	75	17	110	95	37	131	116	58
		2013 using 2016 methodology	113	93	15	130	110	32	147	127	49	164	144	66	181	160	82	197	177	99	214	194	116	231	211	133	248	228	150	265	244	166	281	261	183
		2013 DECC marginal	-98	-118	-196	-71	-91	-169	-43	-63	-142	-16	-36	-114	11	-9	-87	39	19	-59	66	46	-32	93	73	-5	121	101	23	148	128	50	176	155	77
		Proposed 2016	40	20	-58	61	41	-38	81	61	-17	102	81	3	122	102	24	142	122	44	163	143	65	183	163	85	204	184	106	224	204	126	245	225	147
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

Key	Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = kWp PV required

* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

Impact of different CO_2 emission factors

Carbon emissions - note uneven scale

		Emissions reduction	25%			28%			31%			34%			37%			40%			42%			44%			56%			60%		
Detached House	Gas boiler	2010 Part L	-0.6	-0.9	-2.0	-0.4	-0.7	-1.8	-0.2	-0.5	-1.6	0.0	-0.3	-1.4	0.2	-0.1	-1.2	0.4	0.1	-1.0	0.5	0.2	-0.8	0.7	0.3	-0.7	1.5	1.1	0.1	1.7	1.4	0.4
		2013 using 2016 methodology	-0.4	-0.7	-1.6	-0.2	-0.5	-1.4	0.0	-0.3	-1.2	0.2	-0.1	-1.0	0.4	0.1	-0.8	0.6	0.3	-0.6	0.7	0.4	-0.5	0.8	0.5	-0.4	1.6	1.3	0.4	1.8	1.5	0.6
		2013 DECC marginal	-0.6	-1.1	-2.5	-0.4	-0.8	-2.2	-0.1	-0.5	-1.9	0.2	-0.3	-1.7	0.4	0.0	-1.4	0.7	0.2	-1.2	0.9	0.4	-1.0	1.0	0.6	-0.8	2.1	1.6	0.2	2.4	2.0	0.6
		Proposed 2016	-0.5	-0.9	-2.0	-0.3	-0.6	-1.8	0.0	-0.4	-1.6	0.2	-0.2	-1.4	0.4	0.0	-1.1	0.6	0.3	-0.9	0.8	0.4	-0.8	0.9	0.6	-0.6	1.8	1.5	0.3	2.1	1.8	0.6
	ASHP	2010 Part L	-1.0	-1.2	-2.0	-0.8	-1.0	-1.8	-0.6	-0.8	-1.6	-0.4	-0.6	-1.4	-0.2	-0.5	-1.2	0.0	-0.3	-1.0	0.1	-0.1	-0.9	0.3	0.0	-0.8	1.1	0.8	0.0	1.3	1.1	0.3
		2013 using 2016 methodology	0.6	0.3	-0.8	0.8	0.4	-0.6	1.0	0.6	-0.4	1.2	0.8	-0.2	1.4	1.0	0.0	1.6	1.2	0.2	1.7	1.3	0.3	1.8	1.5	0.4	2.6	2.2	1.2	2.8	2.5	1.4
		2013 DECC marginal	-1.1	-1.5	-2.5	-0.9	-1.2	-2.3	-0.6	-1.0	-2.0	-0.4	-0.7	-1.8	-0.1	-0.5	-1.5	0.2	-0.2	-1.2	0.3	0.0	-1.1	0.5	0.1	-0.9	1.5	1.2	0.1	1.9	1.5	0.5
		Proposed 2016	-0.3	-0.6	-1.7	-0.1	-0.4	-1.5	0.2	-0.2	-1.2	0.4	0.0	-1.0	0.6	0.3	-0.8	0.8	0.5	-0.6	1.0	0.6	-0.4	1.1	0.8	-0.3	2.0	1.7	0.6	2.3	2.0	0.9
End Terrace House	Gas boiler	2010 Part L	-0.2	-0.4	-1.2	0.0	-0.2	-1.1	0.1	-0.1	-1.0	0.3	0.0	-0.8	0.4	0.2	-0.7	0.5	0.3	-0.5	0.6	0.4	-0.5	0.7	0.5	-0.4	1.3	1.0	0.2			
		2013 using 2016 methodology	0.0	-0.2	-0.9	0.1	-0.1	-0.8	0.3	0.1	-0.7	0.4	0.2	-0.5	0.5	0.3	-0.4	0.7	0.5	-0.3	0.7	0.5	-0.2	0.8	0.6	-0.1	1.4	1.2	0.4			
		2013 DECC marginal	-0.1	-0.4	-1.5	0.1	-0.2	-1.3	0.3	0.0	-1.2	0.5	0.2	-1.0	0.6	0.3	-0.8	0.8	0.5	-0.6	0.9	0.6	-0.5	1.1	0.8	-0.4	1.8	1.5	0.3			
		Proposed 2016	0.0	-0.3	-1.2	0.1	-0.1	-1.1	0.3	0.0	-0.9	0.4	0.2	-0.8	0.6	0.3	-0.6	0.7	0.5	-0.5	0.8	0.6	-0.4	0.9	0.7	-0.3	1.6	1.3	0.4			
	ASHP	2010 Part L	-0.4	-0.6	-1.2	-0.2	-0.4	-1.1	-0.1	-0.3	-0.9	0.0	-0.1	-0.8	0.2	0.0	-0.7	0.3	0.1	-0.5	0.4	0.2	-0.4	0.5	0.3	-0.3	1.0	0.9	0.2			
		2013 using 2016 methodology	0.8	0.6	-0.3	0.9	0.7	-0.2	1.1	0.8	0.0	1.2	1.0	0.1	1.3	1.1	0.2	1.5	1.2	0.4	1.6	1.3	0.5	1.6	1.4	0.5	2.2	1.9	1.1			
		2013 DECC marginal	-0.4	-0.6	-1.5	-0.2	-0.4	-1.3	0.0	-0.3	-1.1	0.2	-0.1	-0.9	0.3	0.1	-0.8	0.5	0.3	-0.6	0.6	0.4	-0.5	0.7	0.5	-0.4	1.5	1.2	0.4			
		Proposed 2016	0.2	0.0	-0.9	0.4	0.1	-0.8	0.5	0.3	-0.6	0.7	0.4	-0.4	0.8	0.6	-0.3	1.0	0.7	-0.1	1.1	0.8	0.0	1.2	0.9	0.1	1.8	1.6	0.7			
Mid Terrace House	Gas boiler	2010 Part L	-0.1	-0.3	-1.0	0.0	-0.1	-0.9	0.1	0.0	-0.8	0.2	0.1	-0.7	0.4	0.2	-0.5	0.5	0.3	-0.4	0.6	0.4	-0.3	0.7	0.5	-0.2	1.1	1.0	0.2			
		2013 using 2016 methodology	0.0	-0.1	-0.7	0.2	0.0	-0.6	0.3	0.1	-0.5	0.4	0.3	-0.4	0.5	0.4	-0.3	0.6	0.5	-0.2	0.7	0.6	-0.1	0.8	0.7	0.0	1.3	1.1	0.5			
		2013 DECC marginal	0.0	-0.2	-1.2	0.1	-0.1	-1.1	0.3	0.1	-0.9	0.4	0.3	-0.8	0.6	0.4	-0.6	0.8	0.6	-0.4	0.9	0.7	-0.3	1.0	0.8	-0.2	1.6	1.4	0.4			
		Proposed 2016	0.0	-0.2	-1.0	0.1	0.0	-0.9	0.3	0.1	-0.7	0.4	0.3	-0.6	0.6	0.4	-0.4	0.7	0.5	-0.3	0.8	0.6	-0.2	0.9	0.7	-0.1	1.4	1.3	0.4			
	ASHP	2010 Part L	-0.3	-0.4	-1.0	-0.2	-0.3	-0.8	0.0	-0.1	-0.7	0.1	0.0	-0.6	0.2	0.1	-0.5	0.3	0.2	-0.4	0.4	0.3	-0.3	0.5	0.4	-0.2	1.0	0.9	0.3			
		2013 using 2016 methodology	0.8	0.7	-0.1	0.9	0.8	0.0	1.0	0.9	0.1	1.2	1.0	0.2	1.3	1.1	0.4	1.4	1.2	0.5	1.5	1.3	0.5	1.6	1.4	0.6	2.0	1.9	1.1			
		2013 DECC marginal	-0.2	-0.4	-1.2	-0.1	-0.2	-1.0	0.1	-0.1	-0.9	0.2	0.1	-0.7	0.4	0.2	-0.5	0.6	0.4	-0.4	0.7	0.5	-0.3	0.8	0.6	-0.2	1.4	1.2	0.5			
		Proposed 2016	0.3	0.1	-0.7	0.4	0.3	-0.5	0.5	0.4	-0.4	0.7	0.5	-0.2	0.8	0.7	-0.1	1.0	0.8	0.0	1.1	0.9	0.1	1.1	1.0	0.2	1.7	1.5	0.8			
3-Storey Apartment Block	Gas boiler	2010 Part L	-2	-5	-18	0	-3	-15	3	-1	-13	5	1	-11	7	4	-9	10	6	-6	11	8	-5	13	9	-3						
		2013 using 2016 methodology	1	-2	-13	4	0	-10	6	2	-8	8	5	-6	10	7	-4	12	9	-2	14	10	0	15	12	1						
		2013 DECC marginal	0	-5	-21	3	-2	-19	6	1	-16	9	4	-13	12	7	-10	15	10	-7	17	12	-5	19	14	-3						
		Proposed 2016	1	-3	-17	3	-1	-15	6	2	-12	8	4	-9	11	7	-7	14	9	-4	15	11	-3	17	13	-1						
	ASHP	2010 Part L	-4	-7	-16	-2	-4	-14	1	-2	-11	3	0	-9	5	2	-7	7	5	-5	9	6	-3	10	8	-2						
		2013 using 2016 methodology	17	13	1	19	15	3	21	17	5	23	19	7	25	22	9	28	24	11	29	25	13	30	27	14						
		2013 DECC marginal	-3	-7	-19	0	-4	-16	3	-1	-13	6	2	-10	9	5	-7	12	8	-4	14	10	-2	16	12	0						
		Proposed 2016	7	3	-10	9	5	-7	12	8	-4	14	11	-2	17	13	1	19	16	3	21	17	5	23	19	7						
4-Storey Apartment Block	Gas boiler	2010 Part L	-2	-7	-23	1	-4	-20	4	-1	-17	6	2	-14	9	5	-11	12	8	-8	14	10	-6	16	12	-4						
		2013 using 2016 methodology	2	-2	-16	5	1	-13	8	4	-10	10	6	-7	13	9	-5	16	12	-2	18	14	0	20	16	2						
		2013 DECC marginal	0	-6	-27	4	-2	-24	8	2	-20	11	6	-16	15	10	-12	19	13	-8	22	16	-6	24	18	-3						
		Proposed 2016	1	-4	-22	4	-1	-18	8	3	-15	11	6	-12	14	9	-8	18	13	-5	20	15	-3	22	17	-1						
	ASHP	2010 Part L	-4	-8	-20	-2	-5	-17	1	-2	-14	4	1	-11	7	4	-8	10	7	-5	12	9	-3	14	11	-1						
		2013 using 2016 methodology	23	18	2	25	21	4	28	24	7	31	26	10	34	29	13	37	32	16	39	34	18	41	36	20						
		2013 DECC marginal	-3	-8	-24	1	-4	-20	5	0	-16	9	4	-12	13	8	-8	16	12	-5	19	14	-2	21	17	0						
		Proposed 2016	9	5	-12	13	8	-8	16	11	-5	20	15	-1	23	18	2	26	21	5	28	24	7	31	26	10						
8-Storey Apartment Block	Gas boiler	2010 Part L	-5	-12	-43	1	-6	-37	7	-1	-31	13	5	-26	18	11	-20	24	16	-14	28	20	-10	32	24	-7	54	47	16	62	54	24
		2013 using 2016 methodology	4	-3	-29	10	2	-24	15	8	-18	21	13	-13	26	19	-7	31	24	-2	35	28	2	39	31	5	60	53	27	68	60	34
		2013 DECC marginal	0	-10	-51	8	-3	-44	15	5	-36	22	12	-29	30	20	-22	37	27	-14	42	32	-9	47	37	-4	77	66	25	86	76	35
		Proposed 2016	2	-7	-41	9	0	-34	15	6	-28	22	13	-21	28	19	-15	34	26	-8	39	30	-4	43	34	0	69	60	26	77	69	35
	ASHP	2010 Part L	-7	-13	-37	-1	-7	-31	5	-2	-25	10	4	-20	16	10	-14	22	15	-8	26	19	-4	29	23	-1	52	46	22	60	53	30
		2013 using 2016 methodology	46	38	6	52	43	11	57	48	17	63	54	22	68	59	28	73	65	33	77	68	37	81	72	40	102	94	62	110	101	69
		2013 DECC marginal	-3	-11	-43	5	-4	-36	12	4	-28	20	11	-21	27	18	-13	34	26	-6	39	31	-1	44	36	4	74	65	33	84	75	43
		Proposed 2016	21	12	-19	27	19	-13	34	25	-6	40	32	0	47	38	6	53	45	13	57	49	17	62	53	22	88	79	47	96	88	56
20-Storey Apartment Block	Gas boiler	2010 Part L	-11	-28	-103	3	-15	-89	17	-1	-75	31	13	-61	45	27	-47	59	41	-33	68	50	-24	77	60	-15	133	115	41	151	134	60
		2013 using 2016 methodology	11	-6	-69	24	8	-56	37	21	-42	51	34	-29	64	47	-16	77	61	-3	86	70	6	95	78	15	148	132	68	166	149	86
		2013 DECC marginal	1	-22	-122	19	-4	-104	37	14	-86	55	32	-68	73	50	-50	91	68	-32	103	80	-20	115	92	-8	187	164	64	212	188	88
		Proposed 2016	6	-14	-97	22	1	-81	37	17	-65	53	33	-49	69	49	-34	85	64	-18	95	75	-7	106	85	3	169	148	66	190	169	87
	ASHP	2010 Part L	-13	-28	-86	1	-14	-72	15	0	-58	29	14	-45	42	27	-31	56	41	-17	66	51	-8	75	60	2	130	116	57	149	134	76
		2013 using 2016 methodology	117	97	19	130	110	32	143	123	45	157	137	59	170	150	72	183	163	85	192	172	94	201	181	103	254	234	156	272	252	174
		2013 DECC marginal	-2	-22	-100	16	-4	-82	34	14	-64	52	32	-46	70	50	-28	88	68	-10	100	80	2	112	92	14	184	164	86	209	188	110
		Proposed 2016	55	35	-43	71	51	-27	87	67	-11	103	83	4	118	98	20	134	114	36	145	125	46	155	135	57	218	198	120	239	219	141
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

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† SE/SW facing, 45 deg pitch, none/ v. little overshading

Impact of different CO_2 emission factors

Carbon emissions - note uneven scale

Emissions reduction			25%			28%			31%			34%			37%			40%			42%			44%			56%			60%		
Detached House	Gas boiler	2010 Part L	18.0	18.0	18.0	17.3	17.3	17.3	16.5	16.5	16.5	15.8	15.8	15.8	15.1	15.1	15.1	14.4	14.4	14.4	13.9	13.9	13.9	13.4	13.4	13.4	10.6	10.6	10.6	9.6	9.6	9.6
		2013 using 2016 methodology	20.8	20.8	20.8	20.0	20.0	20.0	19.1	19.1	19.1	18.3	18.3	18.3	17.5	17.5	17.5	16.6	16.6	16.6	16.1	16.1	16.1	15.5	15.5	15.5	12.2	12.2	12.2	11.1	11.1	11.1
		2013 DECC marginal	17.5	17.5	17.5	16.8	16.8	16.8	16.1	16.1	16.1	15.4	15.4	15.4	14.7	14.7	14.7	14.0	14.0	14.0	13.5	13.5	13.5	13.1	13.1	13.1	10.3	10.3	10.3	9.3	9.3	9.3
		Proposed 2016	20.4	20.4	20.4	19.6	19.6	19.6	18.7	18.7	18.7	17.9	17.9	17.9	17.1	17.1	17.1	16.3	16.3	16.3	15.8	15.8	15.8	15.2	15.2	15.2	12.0	12.0	12.0	10.9	10.9	10.9
	ASHP	2010 Part L	18.0	18.0	18.0	17.3	17.3	17.3	16.5	16.5	16.5	15.8	15.8	15.8	15.1	15.1	15.1	14.4	14.4	14.4	13.9	13.9	13.9	13.4	13.4	13.4	10.6	10.6	10.6	9.6	9.6	9.6
		2013 using 2016 methodology	20.8	20.8	20.8	20.0	20.0	20.0	19.1	19.1	19.1	18.3	18.3	18.3	17.5	17.5	17.5	16.6	16.6	16.6	16.1	16.1	16.1	15.5	15.5	15.5	12.2	12.2	12.2	11.1	11.1	11.1
		2013 DECC marginal	17.5	17.5	17.5	16.8	16.8	16.8	16.1	16.1	16.1	15.4	15.4	15.4	14.7	14.7	14.7	14.0	14.0	14.0	13.5	13.5	13.5	13.1	13.1	13.1	10.3	10.3	10.3	9.3	9.3	9.3
		Proposed 2016	20.4	20.4	20.4	19.6	19.6	19.6	18.7	18.7	18.7	17.9	17.9	17.9	17.1	17.1	17.1	16.3	16.3	16.3	15.8	15.8	15.8	15.2	15.2	15.2	12.0	12.0	12.0	10.9	10.9	10.9
End Terrace House	Gas boiler	2010 Part L	19.2	19.2	19.2	18.4	18.4	18.4	17.6	17.6	17.6	16.9	16.9	16.9	16.1	16.1	16.1	15.3	15.3	15.3	14.8	14.8	14.8	14.3	14.3	14.3	11.2	11.2	11.2			
		2013 using 2016 methodology	22.2	22.2	22.2	21.3	21.3	21.3	20.4	20.4	20.4	19.5	19.5	19.5	18.6	18.6	18.6	17.7	17.7	17.7	17.2	17.2	17.2	16.6	16.6	16.6	13.0	13.0	13.0			
		2013 DECC marginal	18.6	18.6	18.6	17.9	17.9	17.9	17.1	17.1	17.1	16.4	16.4	16.4	15.6	15.6	15.6	14.9	14.9	14.9	14.4	14.4	14.4	13.9	13.9	13.9	10.9	10.9	10.9			
		Proposed 2016	21.7	21.7	21.7	20.8	20.8	20.8	19.9	19.9	19.9	19.1	19.1	19.1	18.2	18.2	18.2	17.3	17.3	17.3	16.8	16.8	16.8	16.2	16.2	16.2	12.7	12.7	12.7			
	ASHP	2010 Part L	19.2	19.2	19.2	18.4	18.4	18.4	17.6	17.6	17.6	16.9	16.9	16.9	16.1	16.1	16.1	15.3	15.3	15.3	14.8	14.8	14.8	14.3	14.3	14.3	11.2	11.2	11.2			
		2013 using 2016 methodology	22.2	22.2	22.2	21.3	21.3	21.3	20.4	20.4	20.4	19.5	19.5	19.5	18.6	18.6	18.6	17.7	17.7	17.7	17.2	17.2	17.2	16.6	16.6	16.6	13.0	13.0	13.0			
		2013 DECC marginal	18.6	18.6	18.6	17.9	17.9	17.9	17.1	17.1	17.1	16.4	16.4	16.4	15.6	15.6	15.6	14.9	14.9	14.9	14.4	14.4	14.4	13.9	13.9	13.9	10.9	10.9	10.9			
		Proposed 2016	21.7	21.7	21.7	20.8	20.8	20.8	19.9	19.9	19.9	19.1	19.1	19.1	18.2	18.2	18.2	17.3	17.3	17.3	16.8	16.8	16.8	16.2	16.2	16.2	12.7	12.7	12.7			
Mid Terrace House	Gas boiler	2010 Part L	17.2	17.2	17.2	16.5	16.5	16.5	15.8	15.8	15.8	15.1	15.1	15.1	14.4	14.4	14.4	13.7	13.7	13.7	13.3	13.3	13.3	12.8	12.8	12.8	10.1	10.1	10.1			
		2013 using 2016 methodology	19.9	19.9	19.9	19.1	19.1	19.1	18.3	18.3	18.3	17.5	17.5	17.5	16.7	16.7	16.7	15.9	15.9	15.9	15.4	15.4	15.4	14.9	14.9	14.9	11.7	11.7	11.7			
		2013 DECC marginal	16.6	16.6	16.6	16.0	16.0	16.0	15.3	15.3	15.3	14.6	14.6	14.6	14.0	14.0	14.0	13.3	13.3	13.3	12.9	12.9	12.9	12.4	12.4	12.4	9.8	9.8	9.8			
		Proposed 2016	19.4	19.4	19.4	18.6	18.6	18.6	17.9	17.9	17.9	17.1	17.1	17.1	16.3	16.3	16.3	15.5	15.5	15.5	15.0	15.0	15.0	14.5	14.5	14.5	11.4	11.4	11.4			
	ASHP	2010 Part L	17.2	17.2	17.2	16.5	16.5	16.5	15.8	15.8	15.8	15.1	15.1	15.1	14.4	14.4	14.4	13.7	13.7	13.7	13.3	13.3	13.3	12.8	12.8	12.8	10.1	10.1	10.1			
		2013 using 2016 methodology	19.9	19.9	19.9	19.1	19.1	19.1	18.3	18.3	18.3	17.5	17.5	17.5	16.7	16.7	16.7	15.9	15.9	15.9	15.4	15.4	15.4	14.9	14.9	14.9	11.7	11.7	11.7			
		2013 DECC marginal	16.6	16.6	16.6	16.0	16.0	16.0	15.3	15.3	15.3	14.6	14.6	14.6	14.0	14.0	14.0	13.3	13.3	13.3	12.9	12.9	12.9	12.4	12.4	12.4	9.8	9.8	9.8			
		Proposed 2016	19.4	19.4	19.4	18.6	18.6	18.6	17.9	17.9	17.9	17.1	17.1	17.1	16.3	16.3	16.3	15.5	15.5	15.5	15.0	15.0	15.0	14.5	14.5	14.5	11.4	11.4	11.4			
3-Storey Apartment Block	Gas boiler	2010 Part L	18.6	18.6	18.6	17.8	17.8	17.8	17.1	17.1	17.1	16.4	16.4	16.4	15.6	15.6	15.6	14.9	14.9	14.9	14.4	14.4	14.4	13.9	13.9	13.9						
		2013 using 2016 methodology	21.5	21.5	21.5	20.7	20.7	20.7	19.8	19.8	19.8	19.0	19.0	19.0	18.1	18.1	18.1	17.2	17.2	17.2	16.7	16.7	16.7	16.1	16.1	16.1						
		2013 DECC marginal	18.0	18.0	18.0	17.3	17.3	17.3	16.6	16.6	16.6	15.8	15.8	15.8	15.1	15.1	15.1	14.4	14.4	14.4	13.9	13.9	13.9	13.4	13.4	13.4						
		Proposed 2016	21.0	21.0	21.0	20.2	20.2	20.2	19.3	19.3	19.3	18.5	18.5	18.5	17.6	17.6	17.6	16.8	16.8	16.8	16.2	16.2	16.2	15.7	15.7	15.7						
	ASHP	2010 Part L	18.6	18.6	18.6	17.8	17.8	17.8	17.1	17.1	17.1	16.4	16.4	16.4	15.6	15.6	15.6	14.9	14.9	14.9	14.4	14.4	14.4	13.9	13.9	13.9						
		2013 using 2016 methodology	21.5	21.5	21.5	20.7	20.7	20.7	19.8	19.8	19.8	19.0	19.0	19.0	18.1	18.1	18.1	17.2	17.2	17.2	16.7	16.7	16.7	16.1	16.1	16.1						
		2013 DECC marginal	18.0	18.0	18.0	17.3	17.3	17.3	16.6	16.6	16.6	15.8	15.8	15.8	15.1	15.1	15.1	14.4	14.4	14.4	13.9	13.9	13.9	13.4	13.4	13.4						
		Proposed 2016	21.0	21.0	21.0	20.2	20.2	20.2	19.3	19.3	19.3	18.5	18.5	18.5	17.6	17.6	17.6	16.8	16.8	16.8	16.2	16.2	16.2	15.7	15.7	15.7						
4-Storey Apartment Block	Gas boiler	2010 Part L	18.1	18.1	18.1	17.4	17.4	17.4	16.7	16.7	16.7	16.0	16.0	16.0	15.2	15.2	15.2	14.5	14.5	14.5	14.0	14.0	14.0	13.5	13.5	13.5						
		2013 using 2016 methodology	21.0	21.0	21.0	20.2	20.2	20.2	19.3	19.3	19.3	18.5	18.5	18.5	17.7	17.7	17.7	16.8	16.8	16.8	16.3	16.3	16.3	15.7	15.7	15.7						
		2013 DECC marginal	17.6	17.6	17.6	16.9	16.9	16.9	16.2	16.2	16.2	15.5	15.5	15.5	14.8	14.8	14.8	14.0	14.0	14.0	13.6	13.6	13.6	13.1	13.1	13.1						
		Proposed 2016	20.5	20.5	20.5	19.7	19.7	19.7	18.8	18.8	18.8	18.0	18.0	18.0	17.2	17.2	17.2	16.4	16.4	16.4	15.8	15.8	15.8	15.3	15.3	15.3						
	ASHP	2010 Part L	18.1	18.1	18.1	17.4	17.4	17.4	16.7	16.7	16.7	16.0	16.0	16.0	15.2	15.2	15.2	14.5	14.5	14.5	14.0	14.0	14.0	13.5	13.5	13.5						
		2013 using 2016 methodology	21.0	21.0	21.0	20.2	20.2	20.2	19.3	19.3	19.3	18.5	18.5	18.5	17.7	17.7	17.7	16.8	16.8	16.8	16.3	16.3	16.3	15.7	15.7	15.7						
		2013 DECC marginal	17.6	17.6	17.6	16.9	16.9	16.9	16.2	16.2	16.2	15.5	15.5	15.5	14.8	14.8	14.8	14.0	14.0	14.0	13.6	13.6	13.6	13.1	13.1	13.1						
		Proposed 2016	20.5	20.5	20.5	19.7	19.7	19.7	18.8	18.8	18.8	18.0	18.0	18.0	17.2	17.2	17.2	16.4	16.4	16.4	15.8	15.8	15.8	15.3	15.3	15.3						
8-Storey Apartment Block	Gas boiler	2010 Part L	17.5	17.5	17.5	16.8	16.8	16.8	16.1	16.1	16.1	15.4	15.4	15.4	14.7	14.7	14.7	14.0	14.0	14.0	13.5	13.5	13.5	13.0	13.0	13.0	10.2	10.2	10.2	9.3	9.3	9.3
		2013 using 2016 methodology	20.3	20.3	20.3	19.4	19.4	19.4	18.6	18.6	18.6	17.8	17.8	17.8	17.0	17.0	17.0	16.2	16.2	16.2	15.7	15.7	15.7	15.1	15.1	15.1	11.9	11.9	11.9	10.8	10.8	10.8
		2013 DECC marginal	16.9	16.9	16.9	16.2	16.2	16.2	15.5	15.5	15.5	14.9	14.9	14.9	14.2	14.2	14.2	13.5	13.5	13.5	13.1	13.1	13.1	12.6	12.6	12.6	9.9	9.9	9.9	9.0	9.0	9.0
		Proposed 2016	19.7	19.7	19.7	18.9	18.9	18.9	18.1	18.1	18.1	17.4	17.4	17.4	16.6	16.6	16.6	15.8	15.8	15.8	15.2	15.2	15.2	14.7	14.7	14.7	11.6	11.6	11.6	10.5	10.5	10.5
	ASHP	2010 Part L	17.5	17.5	17.5	16.8	16.8	16.8	16.1	16.1	16.1	15.4	15.4	15.4	14.7	14.7	14.7	14.0	14.0	14.0	13.5	13.5	13.5	13.0	13.0	13.0	10.2	10.2	10.2	9.3	9.3	9.3
		2013 using 2016 methodology	20.3	20.3	20.3	19.4	19.4	19.4	18.6	18.6	18.6	17.8	17.8	17.8	17.0	17.0	17.0	16.2	16.2	16.2	15.7	15.7	15.7	15.1	15.1	15.1	11.9	11.9	11.9	10.8	10.8	10.8
		2013 DECC marginal	16.9	16.9	16.9	16.2	16.2	16.2	15.5	15.5	15.5	14.9	14.9	14.9	14.2	14.2	14.2	13.5	13.5	13.5	13.1	13.1	13.1	12.6	12.6	12.6	9.9	9.9	9.9	9.0	9.0	9.0
		Proposed 2016	19.7	19.7	19.7	18.9	18.9	18.9	18.1	18.1	18.1	17.4	17.4	17.4	16.6	16.6	16.6	15.8	15.8	15.8	15.2	15.2	15.2	14.7	14.7	14.7	11.6	11.6	11.6	10.5	10.5	10.5
20-Storey Apartment Block	Gas boiler	2010 Part L	17.1	17.1	17.1	16.4	16.4	16.4	15.7	15.7	15.7	15.0	15.0	15.0	14.3	14.3	14.3	13.7	13.7	13.7	13.2	13.2	13.2	12.7	12.7	12.7	10.0	10.0	10.0	9.1	9.1	9.1
		2013 using 2016 methodology	19.8	19.8	19.8	19.0	19.0	19.0	18.2	18.2	18.2	17.4	17.4	17.4	16.6	16.6	16.6	15.8	15.8	15.8	15.3	15.3	15.3	14.8	14.8	14.8	11.6	11.6	11.6	10.6	10.6	10.6
		2013 DECC marginal	16.5	16.5	16.5	15.8	15.8	15.8	15.2	15.2	15.2	14.5	14.5	14.5	13.9	13.9	13.9	13.2	13.2	13.2	12.8	12.8	12.8	12.3	12.3	12.3	9.7	9.7	9.7	8.8	8.8	8.8
		Proposed 2016	19.3	19.3	19.3	18.5	18.5	18.5	17.7	17.7	17.7	16.9	16.9	16.9	16.2	16.2	16.2	15.4	15.4	15.4	14.9	14.9	14.9	14.4	14.4	14.4	11.3	11.3	11.3	10.3	10.3	10.3
	ASHP	2010 Part L	17.1	17.1	17.1	16.4	16.4	16.4	15.7	15.7	15.7	15.0	15.0	15.0	14.3	14.3	14.3	13.7	13.7	13.7	13.2	13.2	13.2	12.7	12.7	12.7	10.0	10.0	10.0	9.1	9.1	9.1
		2013 using 2016 methodology	19.8	19.8	19.8	19.0	19.0	19.0	18.2	18.2	18.2	17.4	17.4	17.4	16.6	16.6	16.6	15.8	15.8	15.8	15.3	15.3	15.3	14.8	14.8	14.8	11.6	11.6	11.6	10.6	10.6	10.6
		2013 DECC marginal	16.5	16.5	16.5	15.8	15.8	15.8	15.2	15.2	15.2	14.5	14.5	14.5	13.9	13.9	13.9	13.2	13.2	13.2	12.8	12.8	12.8	12.3	12.3	12.3	9.7	9.7	9.7	8.8	8.8	8.8
		Proposed 2016	19.3	19.3	19.3	18.5	18.5	18.5	17.7	17.7	17.7	16.9	16.9	16.9	16.2	16.2	16.2	15.4	15.4	15.4	14.9	14.9	14.9	14.4	14.4	14.4	11.3	11.3	11.3	10.3	10.3	10.3
Fabric specification *			Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C	Int. FEE	FEES	Spec C

Key	Area of solar technology required, as % of ground floor area †	No PV Required	Up to 25%	25% to 40%	Over 40%	Number in cell = Carbon Emissions ($kgCO_{2(eq)}/m^2/yr$)

* Int.FEE = Example interim Fabric Energy Efficiency Standard; FEES = Minimum Fabric Energy Efficiency Standard for 2016; Spec C = Example higher fabric specification

† SE/SW facing, 45 deg pitch, none/ v. little overshading

Appendix B1

Fabric specifications modelled:

- Baseline – Part L 2010 compliant via fabric and gas boiler
- Interim FEE – FEE level of 43 (apartments & mid terrace house) and 52 (End terrace and detached house)
- FEES – FEE level of 39 (apartments & mid terrace house) and 46 (End terrace and detached house) as recommended for zero carbon homes
- Spec C – Advanced specification approaching PassivHaus standards

Fabric specification '2010 Baseline' (achieves 2010 compliance, with gas boiler)

	[East Pennines Location]	Small apartment	Large apartment	Mid terrace house	End terrace house	Detached house
U-values	Ext. Walls (W/m²K)	0.18	0.18	0.18	0.18	0.18
	Party Walls (W/m²K)	0	0	0	0	n/a
	Semi exposed walls, inc adjustment (W/m²K)	0.17	0.17	n/a	n/a	n/a
	Floor (W/m²K)	0.18	0.18	0.18	0.18	0.18
	Roof (W/m²K)	0.13	0.13	0.13	0.13	0.13
	Windows (W/m²K) whole window u-value	1.4 (double glazed)	1.4 (double glazed)	1.6 (double glazed)	1.6 (double glazed)	1.6 (double glazed)
	Doors (W/m²K)	1.2	1.2	1.2	1.2	1.2
	Window g-value	0.63	0.63	0.63	0.63	0.63
	Airtightness (m³/hr/m²)	5.5	5.5	5.1	6.3	6.2
	Thermal bridging y-value (W/m²K)	0.05	0.05	0.05	0.06	0.08
	Ventilation type	Natural	Natural	Natural	Natural	Natural
	Number of extract fans	2	3	4	4	4
	Low energy lighting	100%	100%	100%	100%	100%

Fabric specification 'Interim FEE' (FEE level of 43 (apts & midT) /52 (EndT & detached))

	[East Pennines Location]	Small apartment	Large apartment	Mid terrace house	End terrace house	Detached house
U-values	Ext. Walls (W/m²K)	0.20	0.20	0.20	0.20	0.20
	Party Walls (W/m²K)	0	0	0	0	n/a
	Semi exposed walls, inc adjustment (W/m²K)	0.19	0.19	n/a	n/a	n/a
	Floor (W/m²K)	0.18	0.18	0.17	0.18	0.15
	Roof (W/m²K)	0.15	0.15	0.15	0.15	0.15
	Windows (W/m²K) whole window u-value	1.6 (double glazed)	1.6 (double glazed)	1.5 (double glazed)	1.5 (double glazed)	1.4 (double glazed)
	Doors (W/m²K)	1.2	1.2	1.2	1.2	1.2
	Window g-value	0.63	0.63	0.63	0.63	0.63
	Airtightness (m³/hr/m²)	5	5	5	5.7	5.1
	Thermal bridging y-value (W/m²K)	0.06	0.06	0.06	0.06	0.04
	Ventilation type	Natural	Natural	Natural	Natural	Natural
	Number of extract fans	2	3	4	4	4
	Low energy lighting	100%	100%	100%	100%	100%

Fabric specification 'FEES' (minimum Fabric Energy Efficiency Standard for 2016)

	[East Pennines Location]	Small apartment	Large apartment	Mid terrace house	End terrace house	Detached house
U-values	Ext. Walls (W/m²K)	0.18	0.18	0.18	0.18	0.15
	Party Walls (W/m²K)	0	0	0	0	n/a
	Semi exposed walls, inc adjustment (W/m²K)	0.17	0.17	n/a	n/a	n/a
	Floor (W/m²K)	0.15	0.15	0.17	0.18	0.15
	Roof (W/m²K)	0.13	0.13	0.13	0.13	0.13
	Windows (W/m²K) whole window u-value	1.4 (double glazed)	1.4 (double glazed)	1.4 (double glazed)	1.4 (double glazed)	1.4 (double glazed)
	Doors (W/m²K)	1.0	1.0	1.0	1.0	1.0
	Window g-value	0.63	0.63	0.63	0.63	0.63
	Airtightness (m³/hr/m²)	5	5	5	5	3.1
	Thermal bridging y-value (W/m²K)	0.04	0.04	0.04	0.04	0.04
	Ventilation type	Natural	Natural	Natural	Natural	Natural
	Number of extract fans	2	3	4	4	4
	Low energy lighting	100%	100%	100%	100%	100%

Fabric specification 'Spec C'

		Small apartment	Large apartment	Mid terrace house	End terrace house	Detached house
U-values	Ext. Walls (W/m²K)	0.15	0.15	0.15	0.15	0.15
	Party Walls (W/m²K)	0	0	0	0	n/a
	Semi exposed walls, inc adjustment (W/m²K)	0.14	0.14	n/a	n/a	n/a
	Floor (W/m²K)	0.15	0.15	0.15	0.15	0.15
	Roof (W/m²K)	0.11	0.11	0.11	0.11	0.11
	Windows (W/m²K) whole window u-value	0.8 (triple glazed)	0.8 (triple glazed)	0.8 (triple glazed)	0.8 (triple glazed)	0.8 (triple glazed)
	Doors (W/m²K)	1.0	1.0	1.0	1.0	1.0
	Window g-value	0.57	0.57	0.57	0.57	0.57
	Airtightness (m³/hr/m²)	1	1	1	1	1
	Thermal bridging y-value (W/m²K)	0.04	0.04	0.04	0.04	0.04
	Ventilation type	MVHR	MVHR	MVHR	MVHR	MVHR
	Low energy lighting	100%	100%	100%	100%	100%

Appendix B2

Technical modelling assumptions

Technology performance efficiencies used in modelling

Technology	Specification	Notes
Gas condensing boiler (individual)	95% efficient	Assuming an integrated flue gas heat recovery system - i.e. 91% for condensing boiler + 4% for FGHR. Note that SAP already has an in-use factor for boilers contained in it.
Gas condensing combi boiler (individual)	95% efficient	Assuming an integrated flue gas heat recovery system - i.e. 91% for condensing boiler + 4% for FGHR. Note that SAP already has an in-use factor for boilers contained in it.
ASHP (individual)	250% efficient	Use current SAP default. HP trials said 80% performed worse than expected, however much of this was put down to poor installation. Assumption that by 2016 improvements in installation will bring performance up. So considered reasonable to assume current SAP default - no justification to assume anything different.
GSHP (individual)	320% efficient	Use current SAP default. HP trials said 80% performed worse than expected, however much of this was put down to poor installation. Assumption that by 2016 improvements in installation will bring performance up. So considered reasonable to assume current SAP default - no justification to assume anything different.
Gas boiler (communal)	86% efficient	Limit for non-condensing boilers.
Biomass boiler (communal)	86% efficient	Limit for non-condensing boilers.
Gas CHP (communal)	37% elec efficiency 47% heat efficiency	Confirmed by CHPA, based on 250kWe
Biomass CHP (communal)	17% elec efficiency 60% heat efficiency	Adjusted data from CHPA
Solar hot water	Zero loss collector efficiency = 0.81; heat loss coefficient = 3.9	Confirmed by REA
Photovoltaics	7m²/kWp assumed	Confirmed by REA
MVHR	Specific Fan Power = 0.5 Heat recovery efficiency = 90%	Good practice 2010

Other modelling assumptions

Item	Specification	Notes
DHW cylinder size	Apartments: 120 litre Mid & End terrace: 150 litre Detached: 200 litre	Declared loss factors of 0.96, 1.14 and 1.44 respectively. Water use less than or equal to 125 litres/person/day.
Space heating controls (individual system)	Time & temperature zone control	As proxy for well controlled heating system. To be used in all dwelling types.
Space heating controls (communal system)	Programmer + TRV, charging linked to use	Gives best performance in SAP
Compensator (where applicable)	Weather compensator	Weather and Enhanced Load compensators give same performance boost in SAP.
Communal heating type (where applicable)	100degC or below full control variable system	
Hot water storage for communal heating options	Cylinder in dwelling	It was considered more likely that developers will want to include cylinder in dwelling to help ameliorate occupant concerns over connection to a communal system which is not under their direct control.
Fraction of heat from CHP (where applicable)	To be equivalent to hot water demand	Ratio of hot water demand to total heat demand calculated for each dwelling modelled.
Heat pump (individual)	Use immersion	Use deemed to be likely
Solar hot water	Orientation = South Collector tilt = 30deg Overshading = none/ very little	Optimum performance assumed
Photovoltaics	Orientation = SE/SW Collector tilt = 45deg Overshading = none/ very little	Not quite optimum orientation & tilt.

Technology lifetimes for whole life costing

Item	Lifecycle (years)
Combi boiler	12 (CERT figure)
Boiler	12 (CERT figure)
Communal boiler	20
Cylinder	30
ASHP: Heat pump	18 (RHI figure)
GSHP: Heat pump	23 (RHI figure)
GSHP: Replace glycol	5
GSHP: Borehole pipework	60
Gas CHP (medium 200kW)	15
Gas CHP (large 1MW)	20
Solar hot water: panels	20 (assuming direct flow)
PV: Panels	30
PV: Inverter	12
Exhaust heat recovery unit	18
MVHR heat recovery unit	20

Annual solar radiation, kWh/m²

	Location	
	East Pennines	
Tilt of collector	**South**	**SE/SW**
30°	1096	1040
45°	1083	1013

Appendix C1

Bar graphs showing the Net Present Value over 60 years from fabric and heat technology combinations together with zero carbon electricity generation to achieve a TER of between 20 and 10 kg CO_2 /m^2 .yr.

Modelling assumptions:

- Discount rate – 3.5%
- Learning rates included for replacement and maintenance costs
- DECC central energy prices (**variable** prices)
- 2016 carbon emission factors
- FiT and RHI payments **excluded**
- Gas boiler baseline used for all scenarios

Dwelling types:

- Mid terrace House
- End terrace house
- Detached house
- Apartment in a 4 storey block

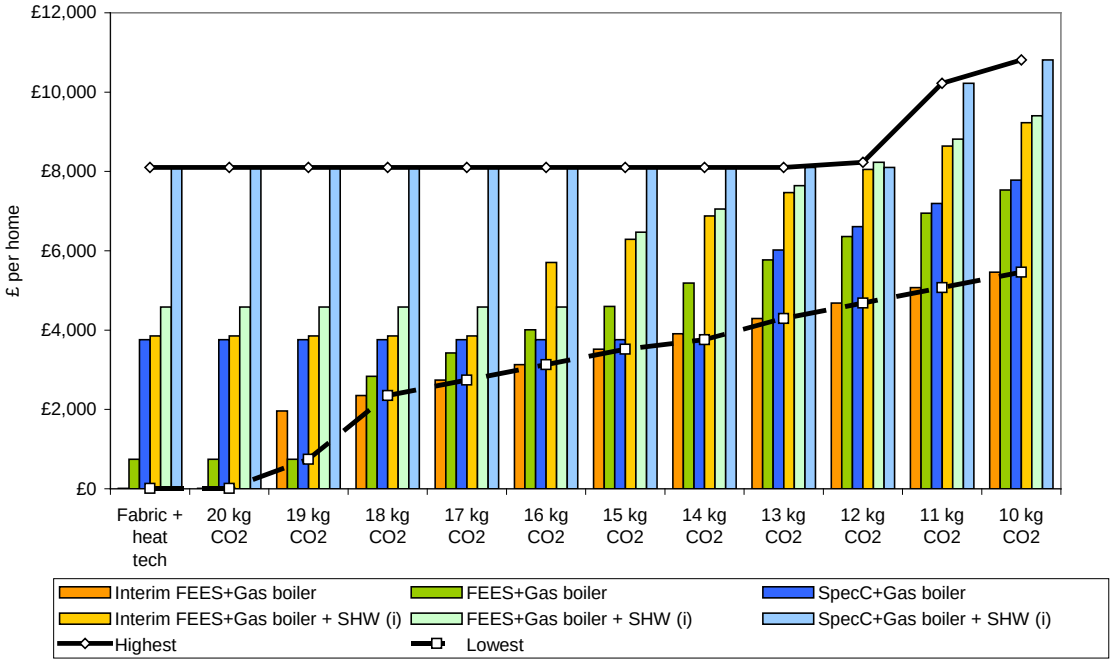
Heat technologies:

- Gas
- Gas + SHW
- ASHP
- ASHP + SHW

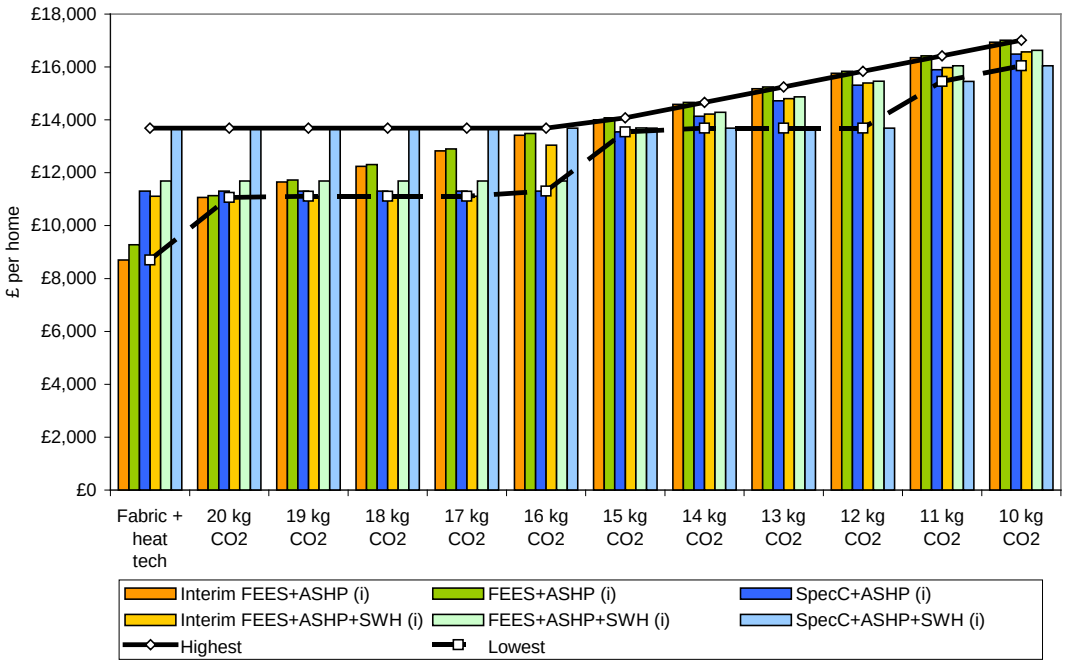
Fabric energy efficiency scenarios:

- Interim FEE
- FEES
- Spec C

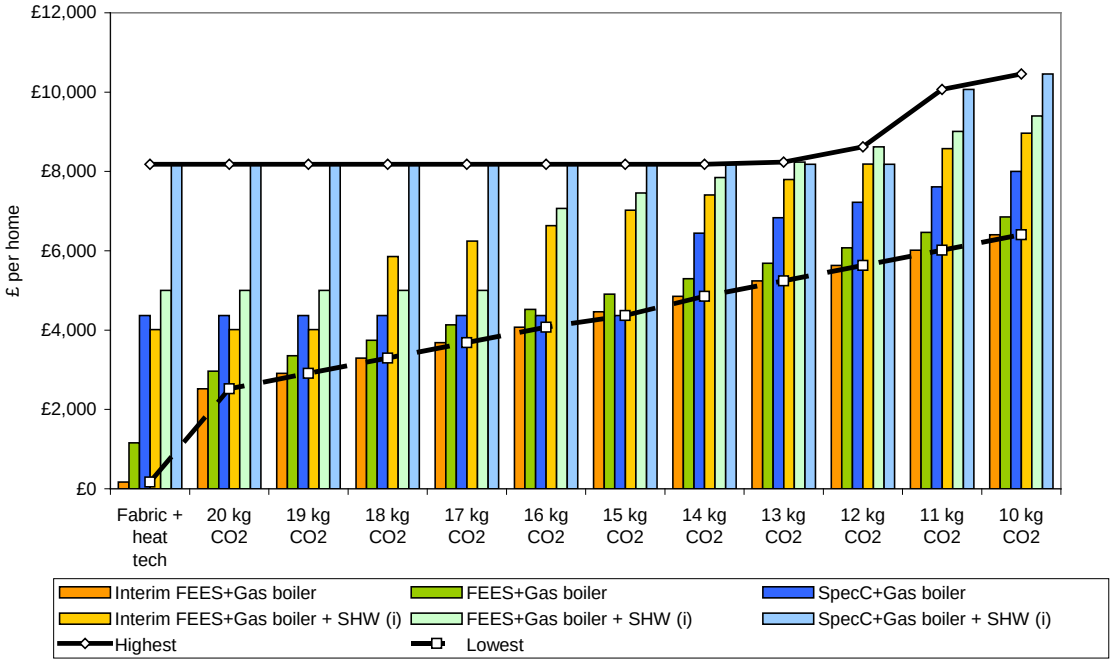
Mid-terrace house - Net present value over 60 years (variable energy excluding FiT / RHI)



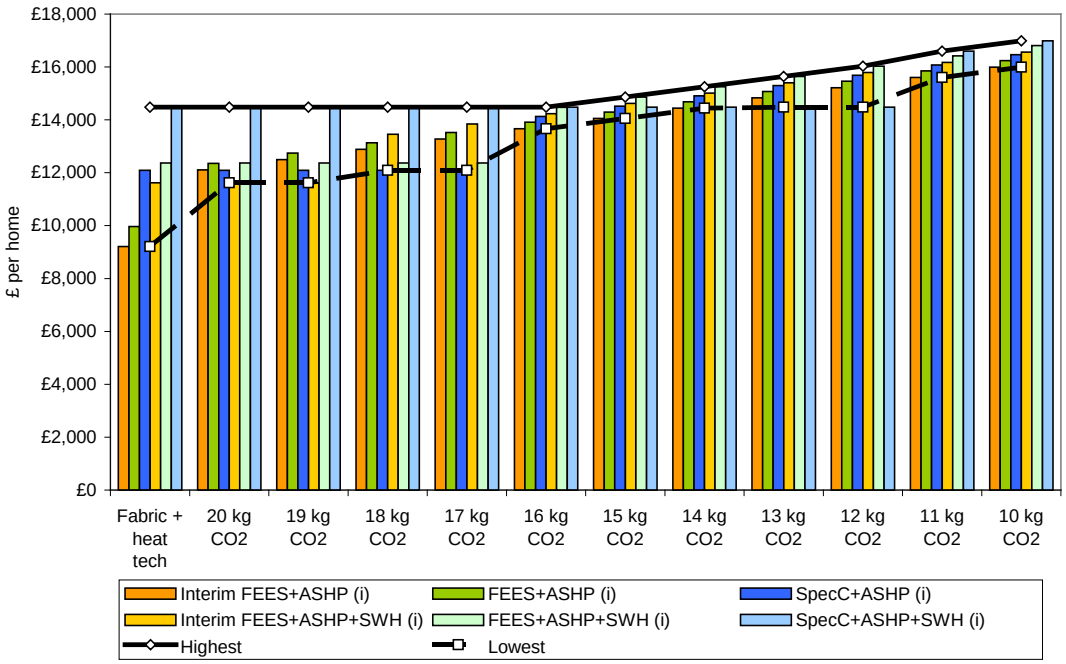
Mid-terrace house - Net present value over 60 years (variable energy excluding FiT / RHI)



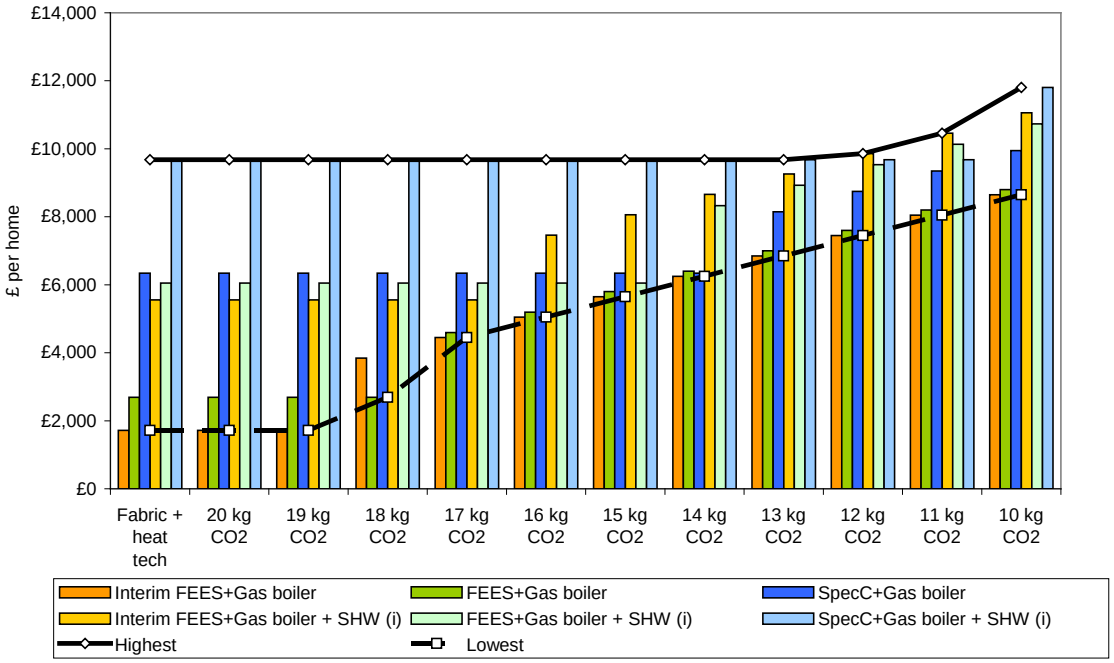
End of terrace house - Net present value over 60 years (variable energy excluding FiT / RHI)



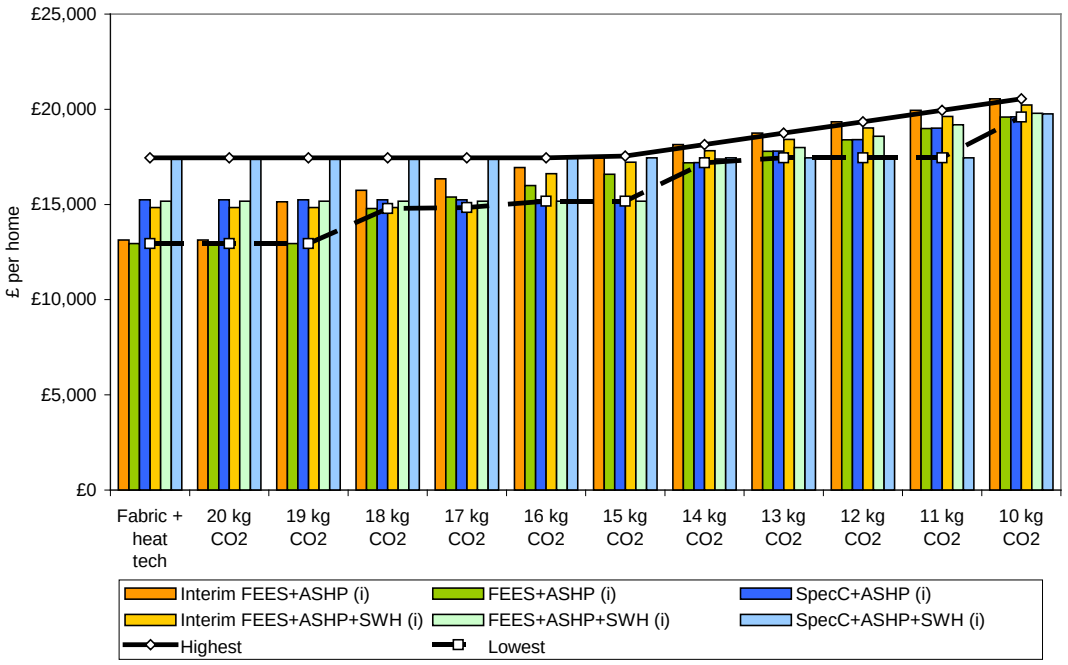
End of terrace house - Net present value over 60 years (variable energy excluding FiT / RHI)



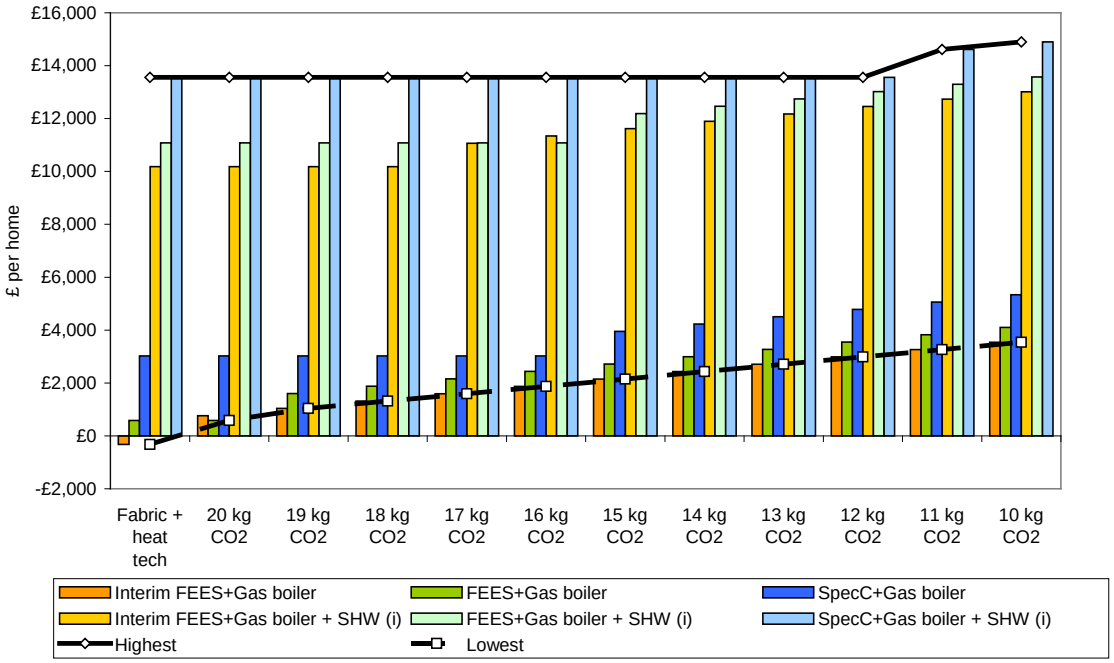
Detached house - Net present value over 60 years (variable energy excluding FiT / RHI)



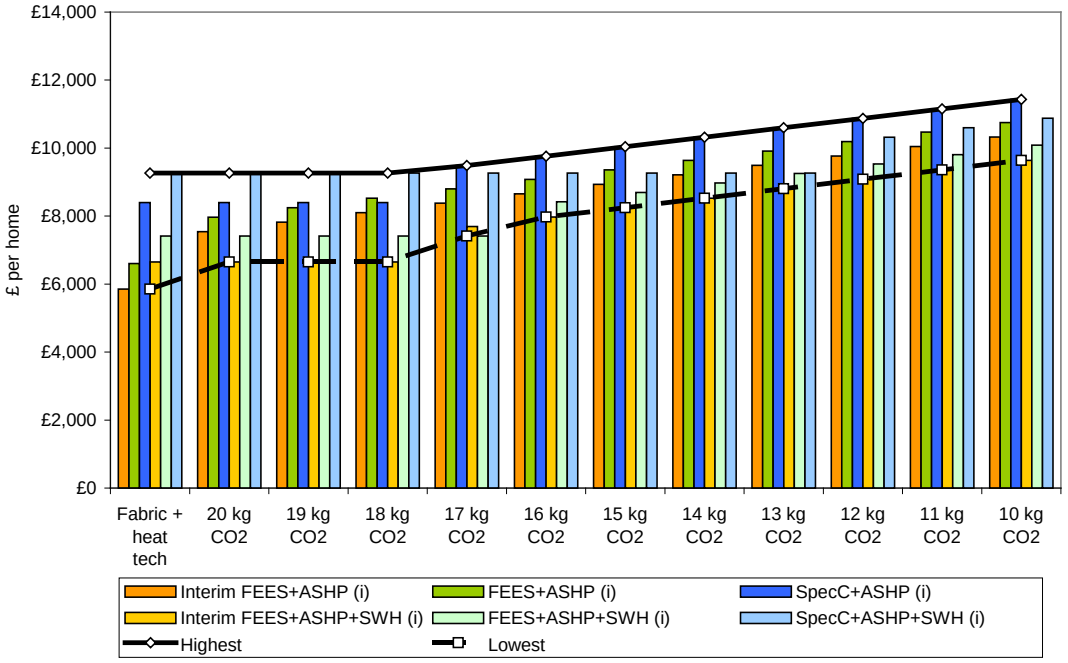
Detached house - Net present value over 60 years (variable energy excluding FiT / RHI)



4 storey apartment - Net present value over 60 years (variable energy excluding FiT / RHI)



4 storey apartment - Net present value over 60 years (variable energy excluding FiT / RHI)



Appendix C2

Bar graphs showing the present value of running costs over 60 years from fabric and heat technology combinations together with zero carbon electricity generation to achieve a TER of between 20 and 10 kg CO_2 m^2 y^1.

Modelling assumptions:

- Discount rate – 3.5%
- Capital cost excluded, replacement and maintenance costs included
- Learning rates included for replacement and maintenance costs
- DECC central energy prices (**domestic** prices)
- 2016 carbon emission factors
- Income from FiT and RHI payments **excluded**
- Gas boiler baseline used for all scenarios

Dwelling types:

- Mid terrace House
- End terrace house
- Detached house
- Apartment in a 4 storey block

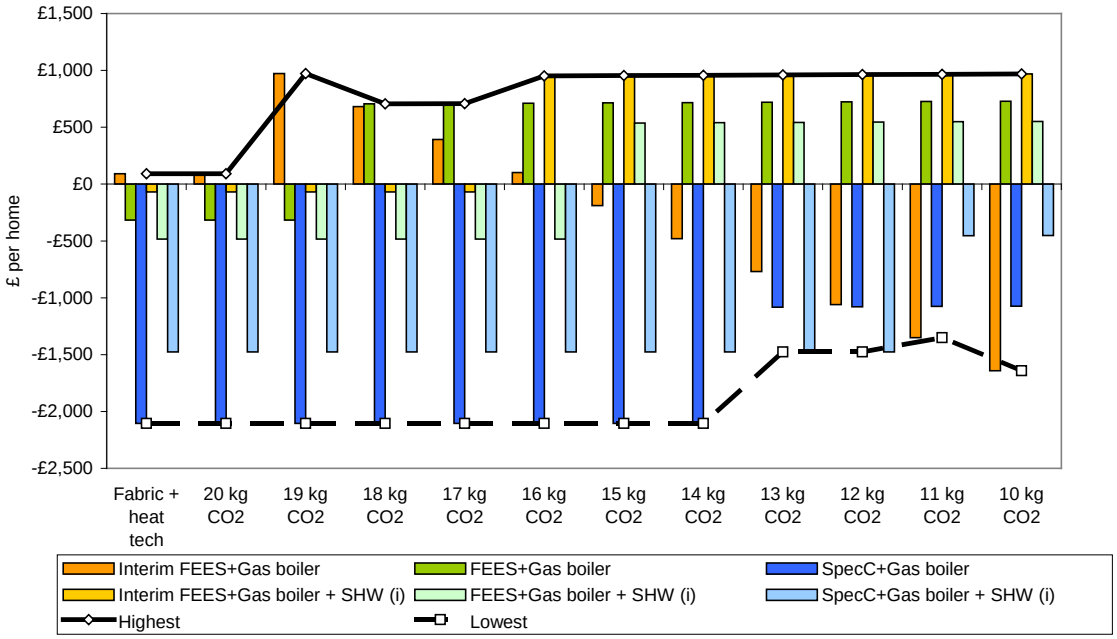
Heat technologies:

- Gas
- Gas + SHW
- ASHP
- ASHP + SHW

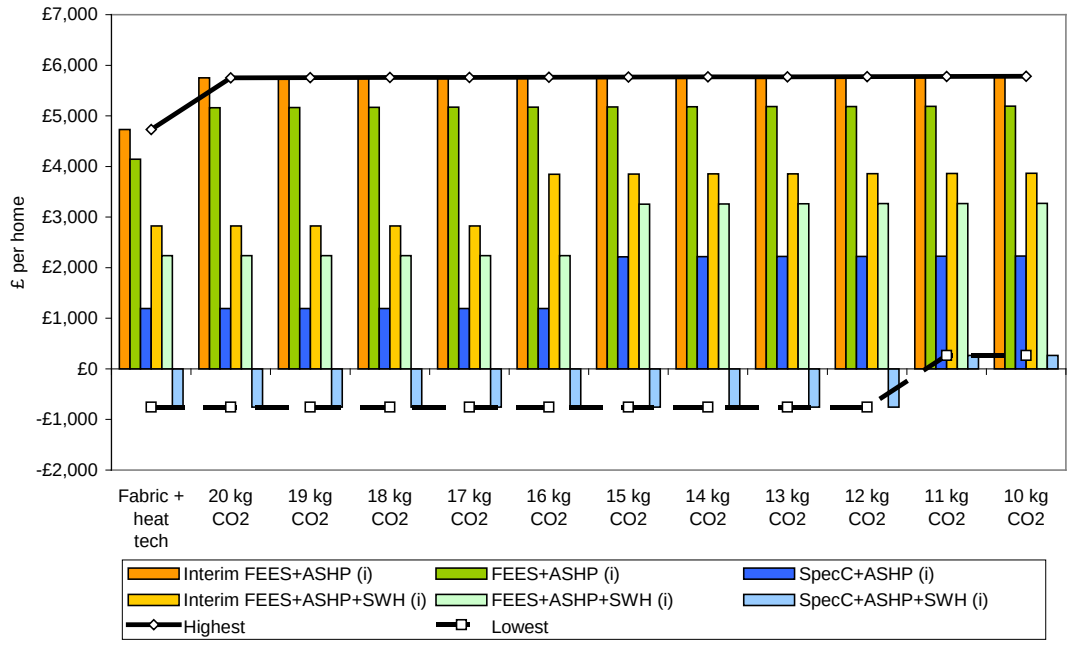
Fabric energy efficiency scenarios:

- Interim FEE
- FEES
- Spec C

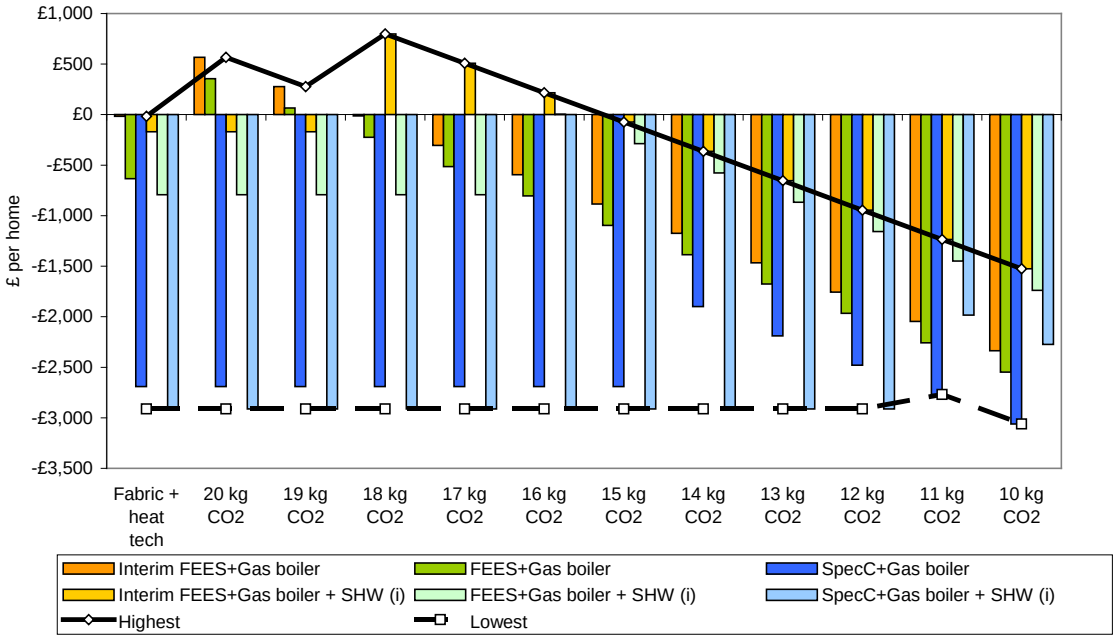
Mid-terrace house - Running costs excluding FiT / RHI)



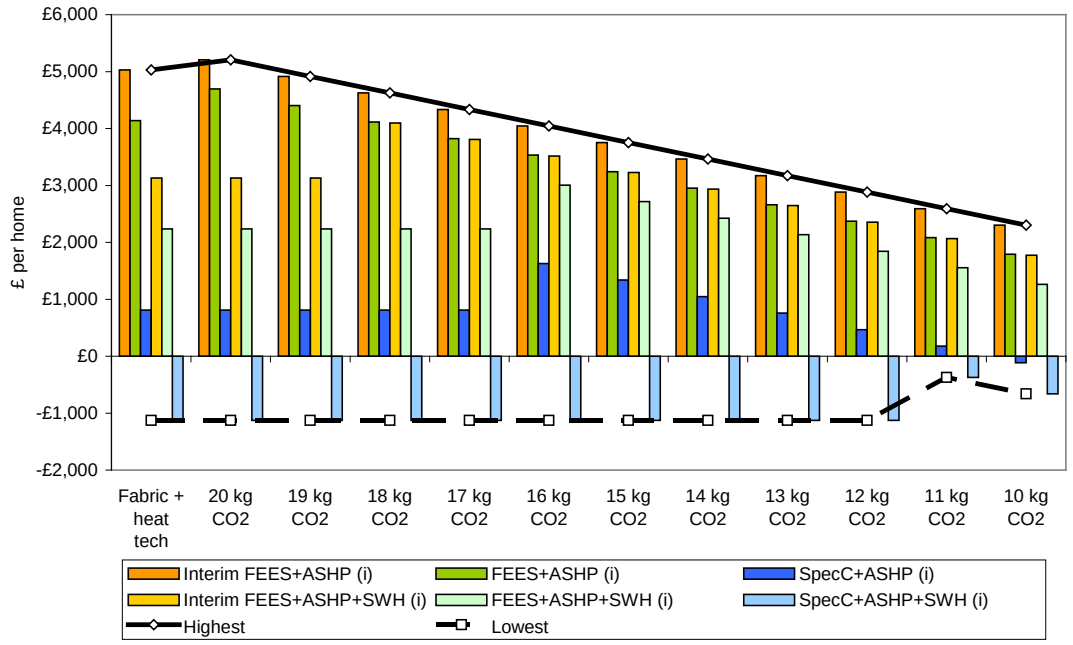
Mid-terrace house - Running costs excluding FiT / RHI)



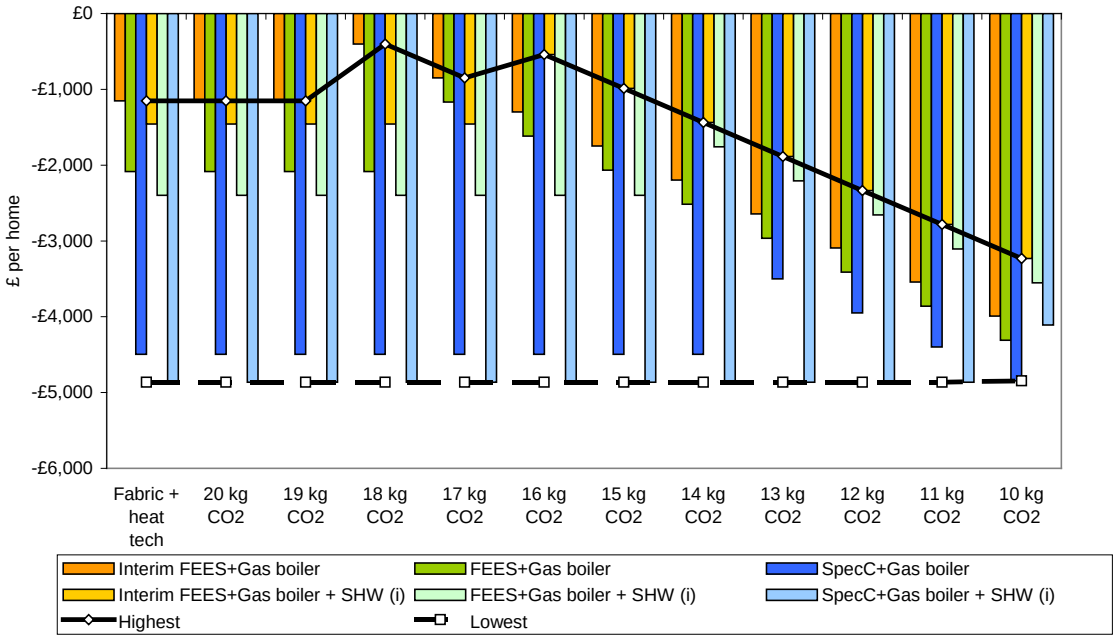
End of terrace house - Running costs excluding FiT / RHI)



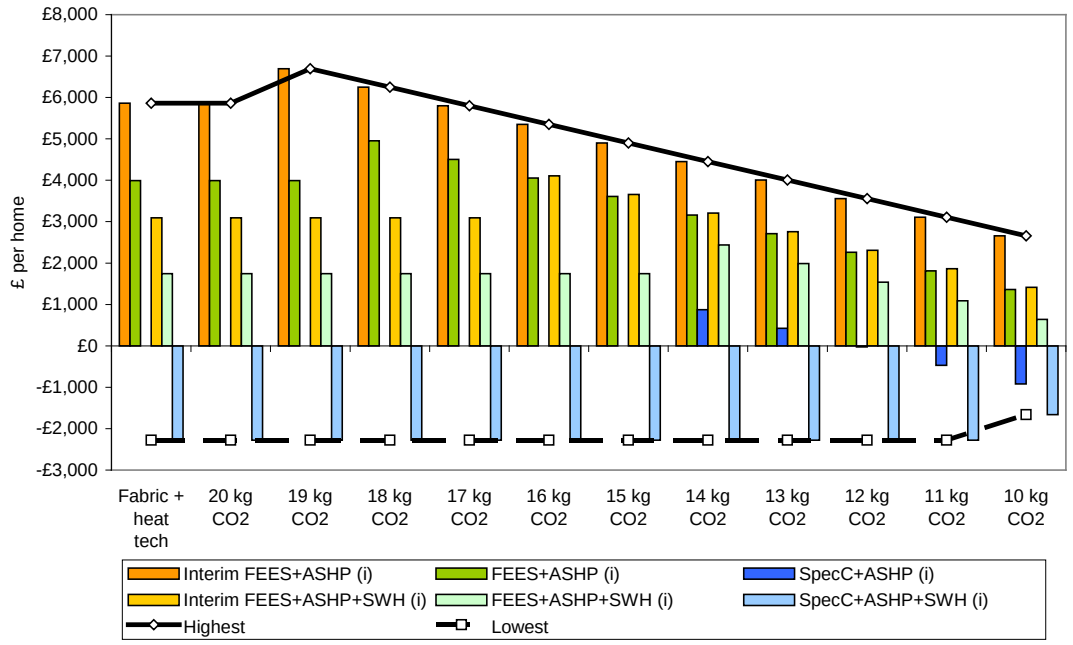
End of terrace house - Running costs excluding FiT / RHI)



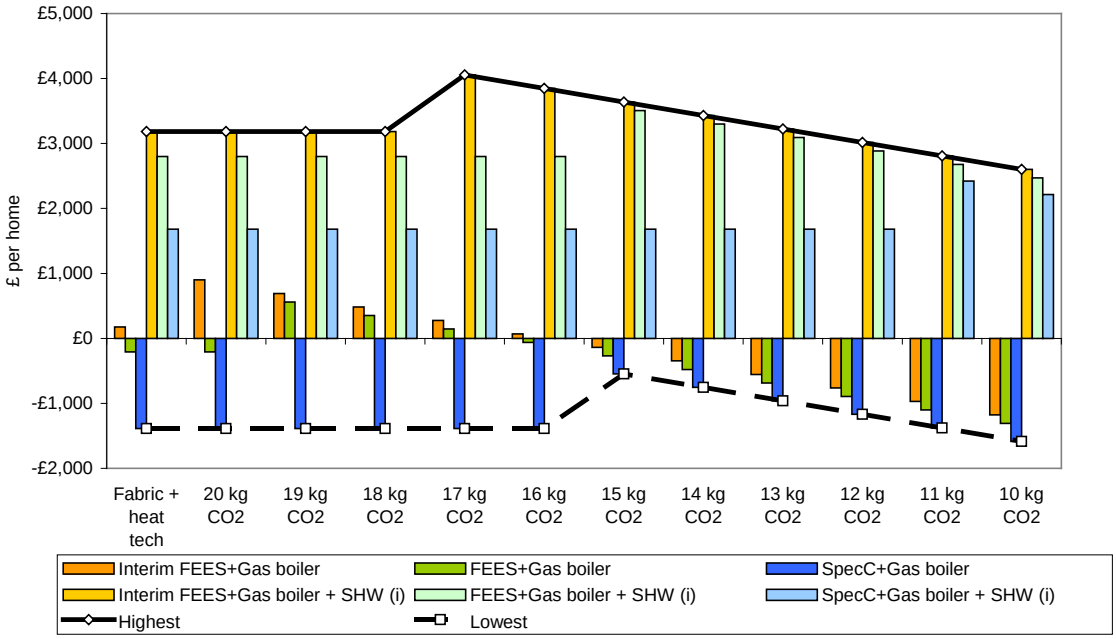
Detached house - Running costs excluding FiT / RHI)



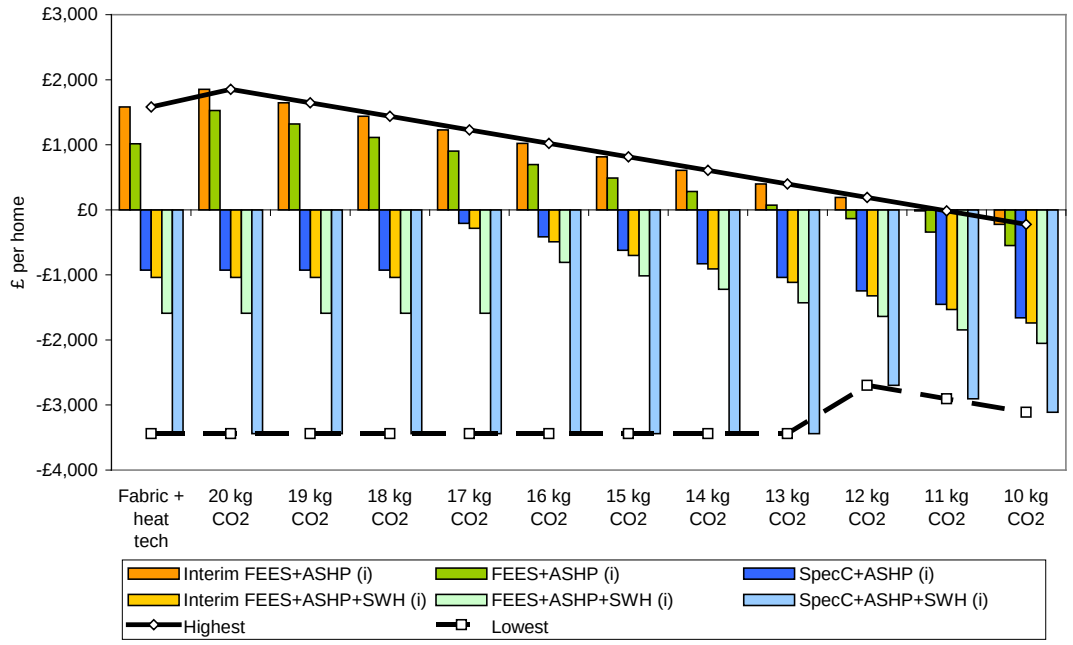
Detached house - Running costs excluding FiT / RHI)



4 storey apartment - Running costs excluding FiT / RHI)



4 storey apartment - Running costs excluding FiT / RHI)



Appendix C3

Bar graphs showing the present value of running costs over 60 years from fabric and heat technology combinations together with zero carbon electricity generation to achieve a TER of between 20 and 10 kg CO_2 m^2 y^1.

Modelling assumptions:

- Discount rate – 3.5%
- Capital cost excluded, replacement and maintenance costs included
- Learning rates included for replacement and maintenance costs
- DECC central energy prices (**domestic** prices)
- 2016 carbon emission factors
- Income from FiT and RHI payments **included**
- Gas boiler baseline used for all scenarios

Dwelling types:

- Mid terrace House
- End terrace house
- Detached house
- Apartment in a 4 storey block

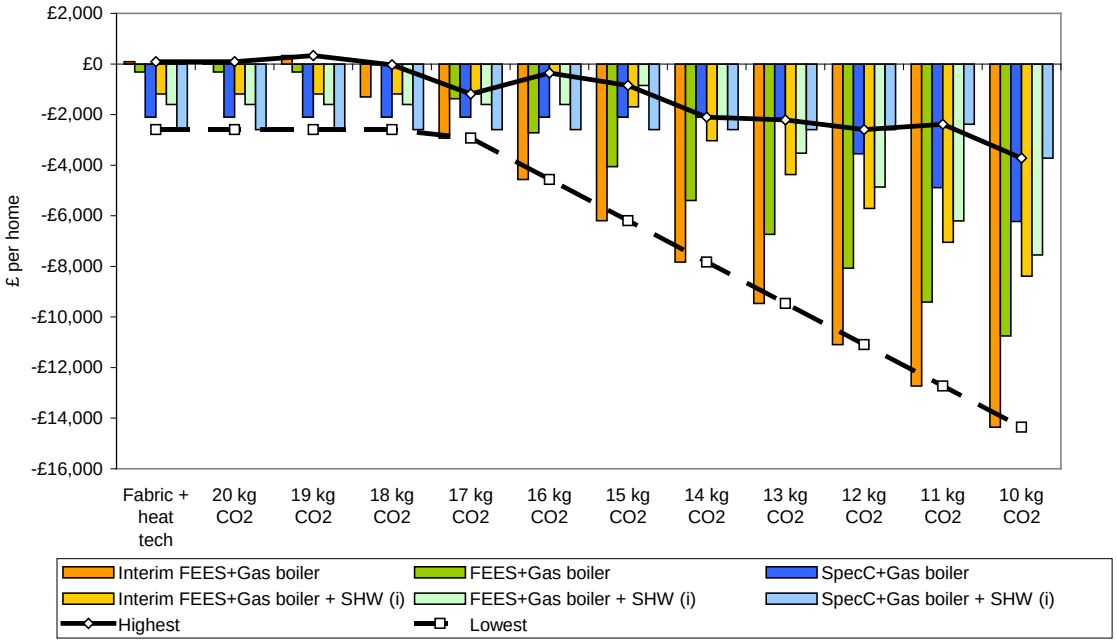
Heat technologies:

- Gas
- Gas + SHW
- ASHP
- ASHP + SHW

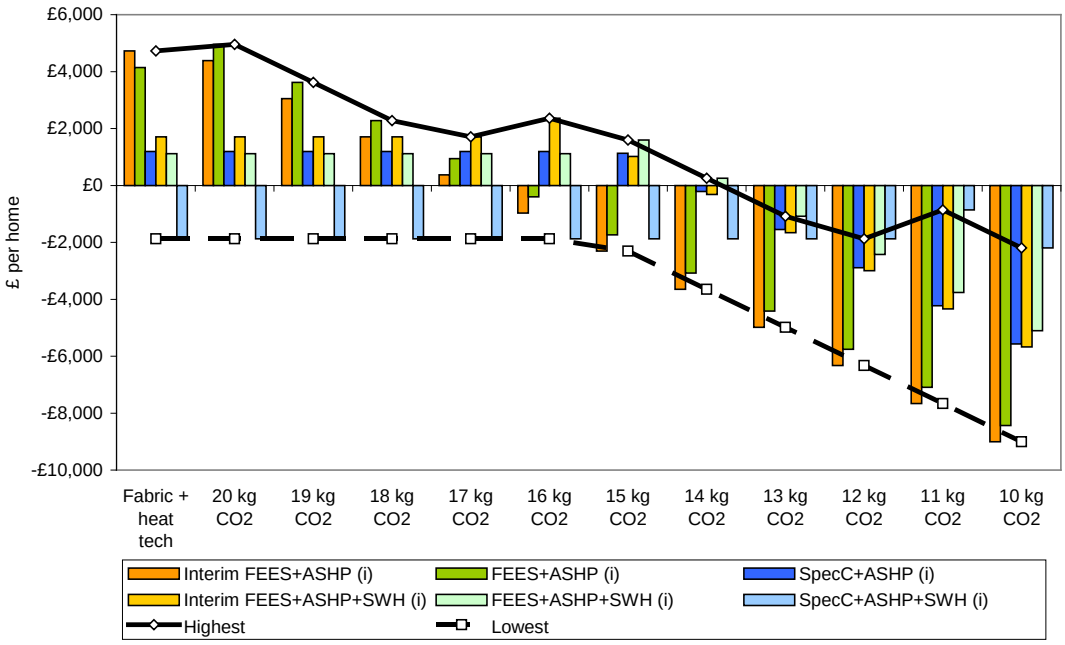
Fabric energy efficiency scenarios:

- Interim FEE
- FEES
- Spec C

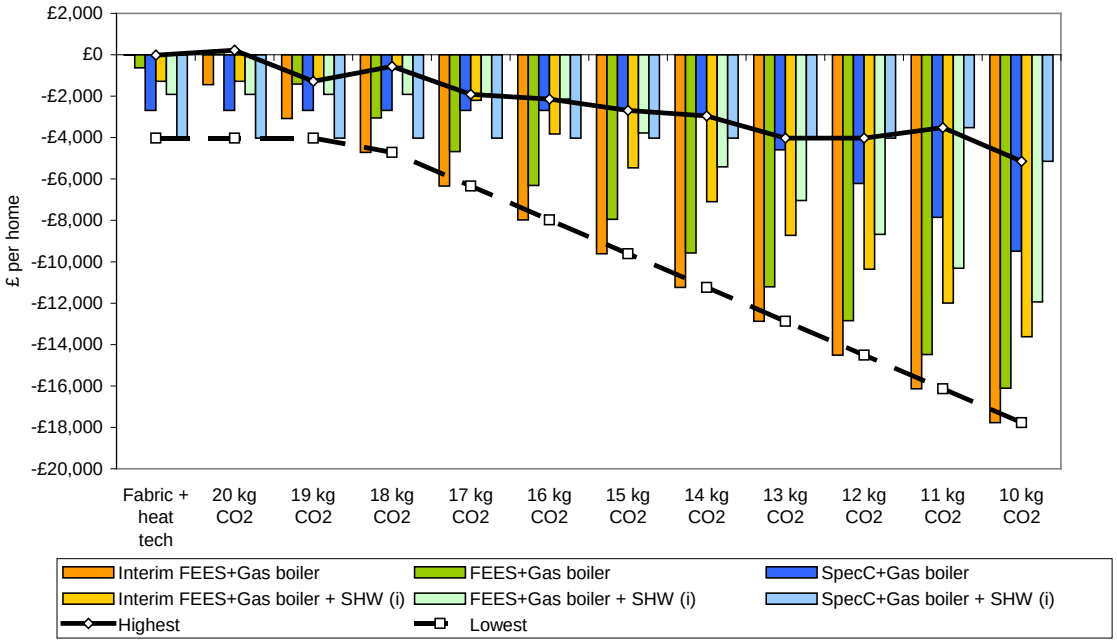
Mid-terrace house - Running costs including FiT / RHI)



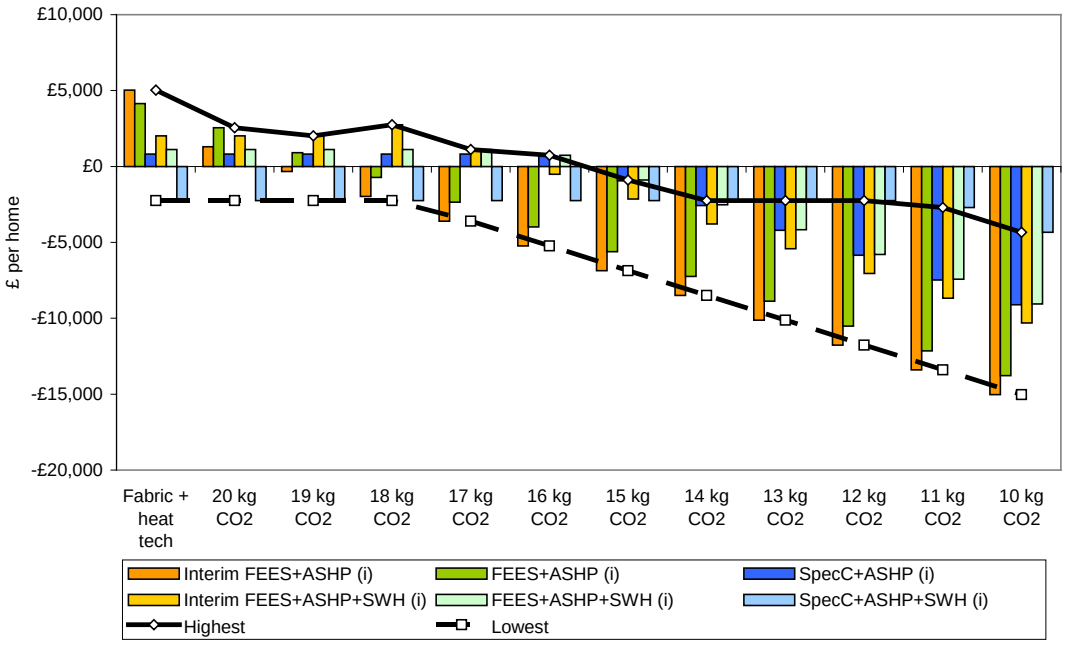
Mid-terrace house - Running costs including FiT / RHI)



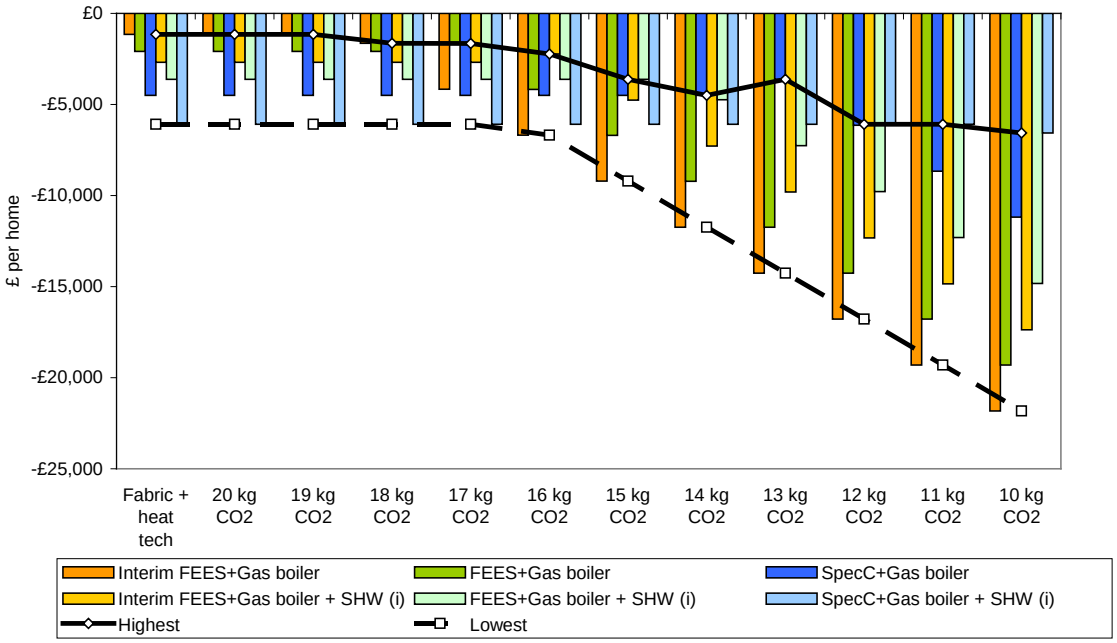
End of terrace house - Running costs including FiT / RHI)



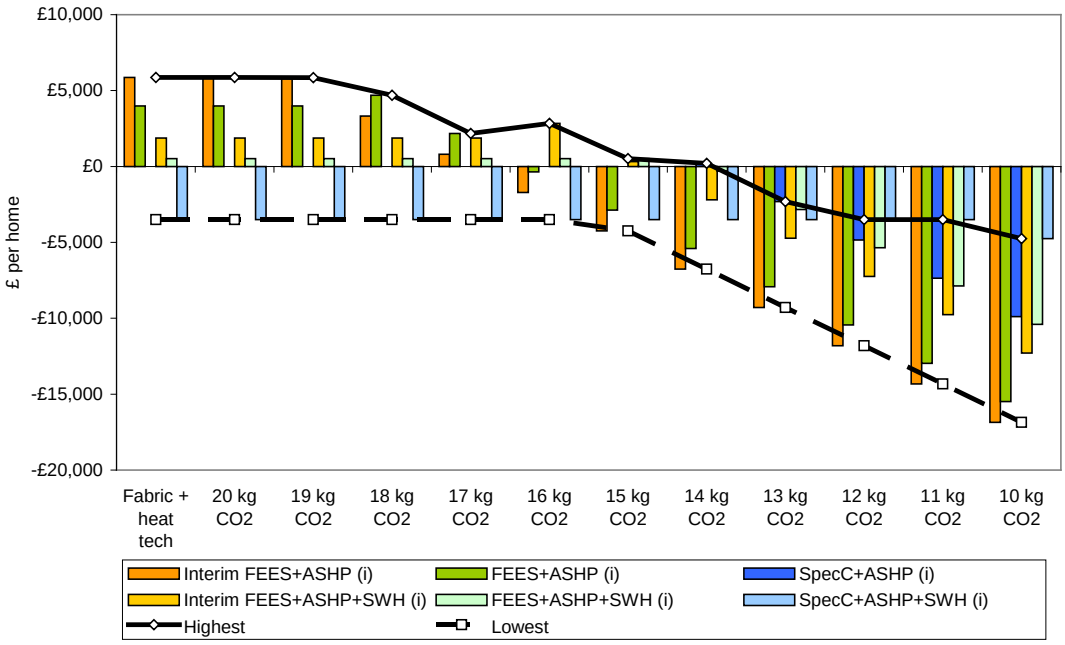
End of terrace house - Running costs including FiT / RHI)



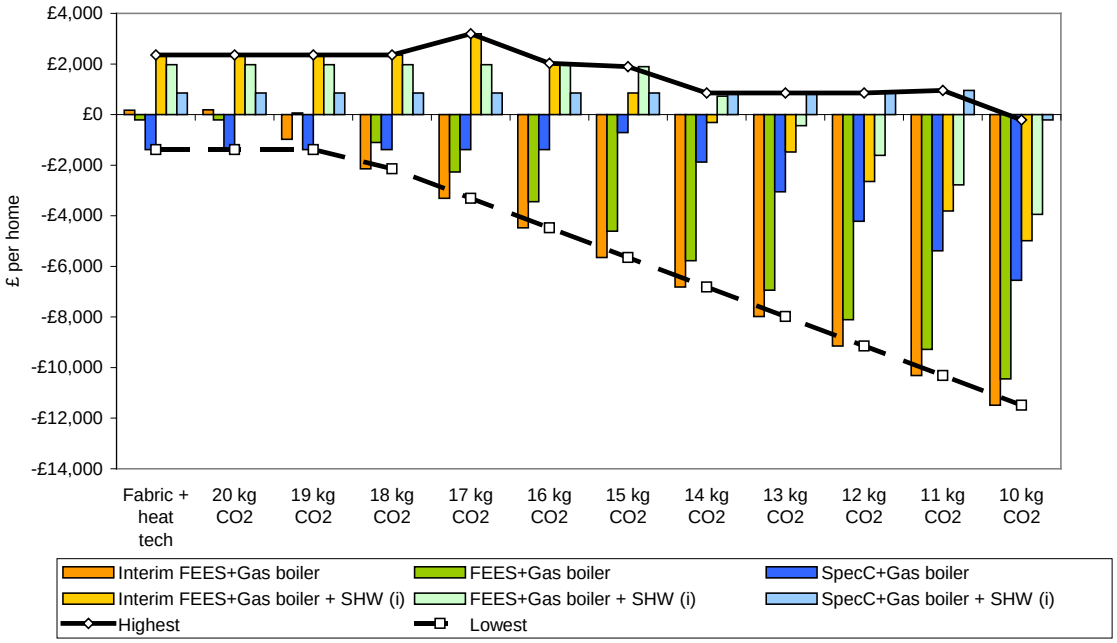
Detached house - Running costs including FiT / RHI)



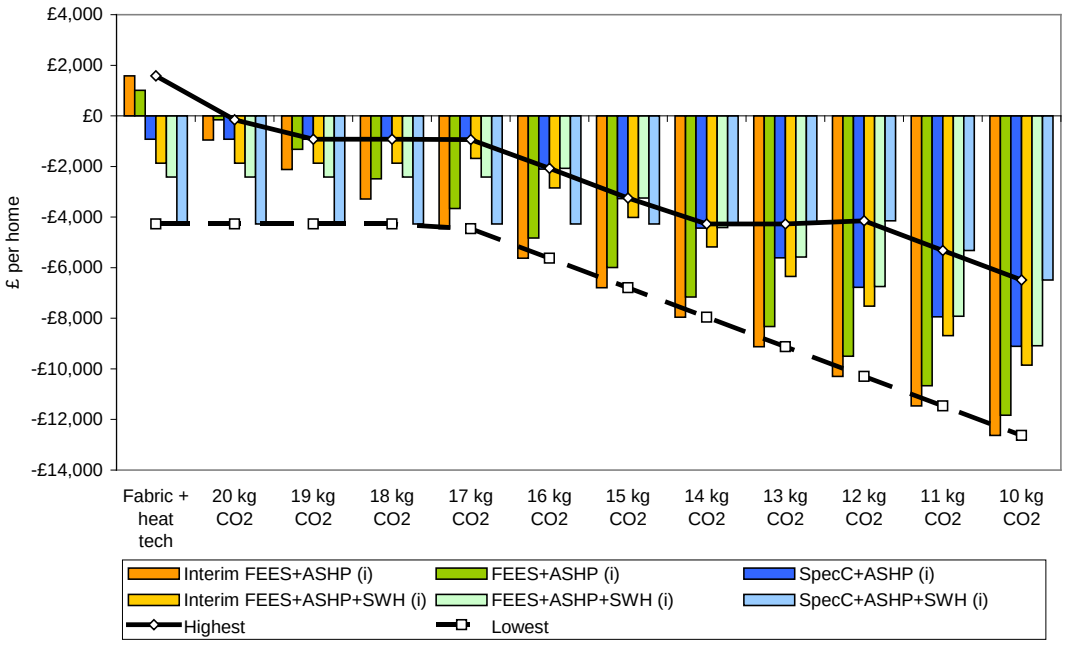
Detached house - Running costs including FiT / RHI)



4 storey apartment - Running costs including FiT / RHI)



4 storey apartment - Running costs including FiT / RHI)



Appendix C4

Bar graphs showing the cost effectiveness of carbon savings over 60 years from fabric and heat technology combinations together with zero carbon electricity generation to achieve a TER of between 20 and 10 kg CO_2 m^2 y^1.

Modelling assumptions:

- Discount rate – 3.5%
- Capital cost excluded, replacement and maintenance costs included
- Learning rates included for replacement and maintenance costs
- DECC central energy prices (**variable** prices)
- 2016 carbon emission factors
- Income from FiT / RHI **excluded**
- Gas boiler baseline used for all scenarios

Dwelling types:

- Mid terrace House
- End terrace house
- Detached house
- Apartment in a 4 storey block

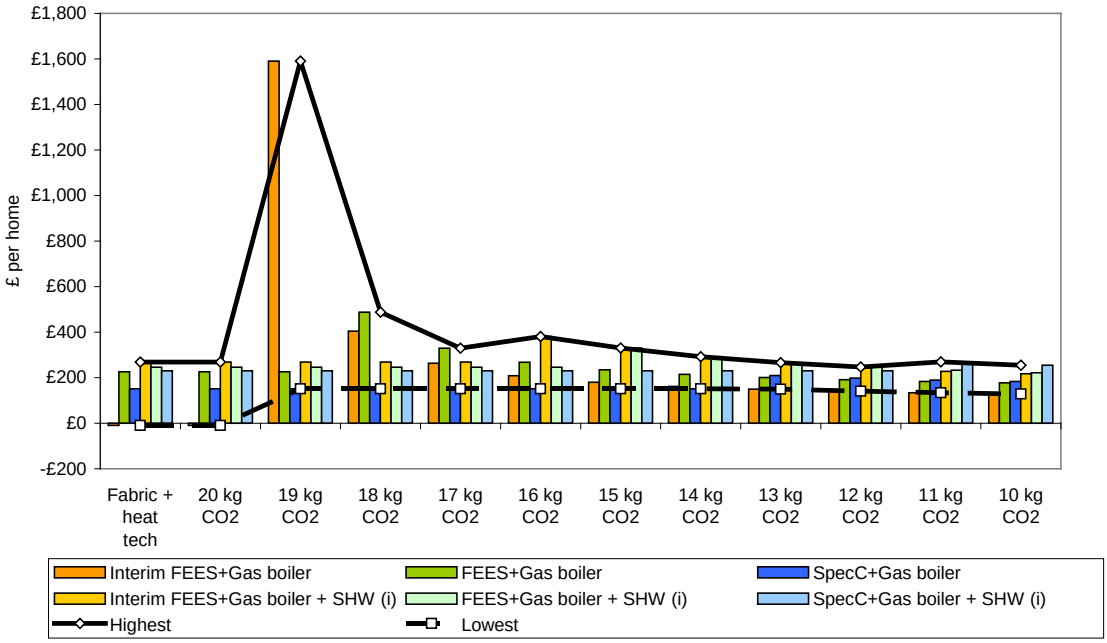
Heat technologies:

- Gas
- Gas + SHW
- ASHP
- ASHP + SHW

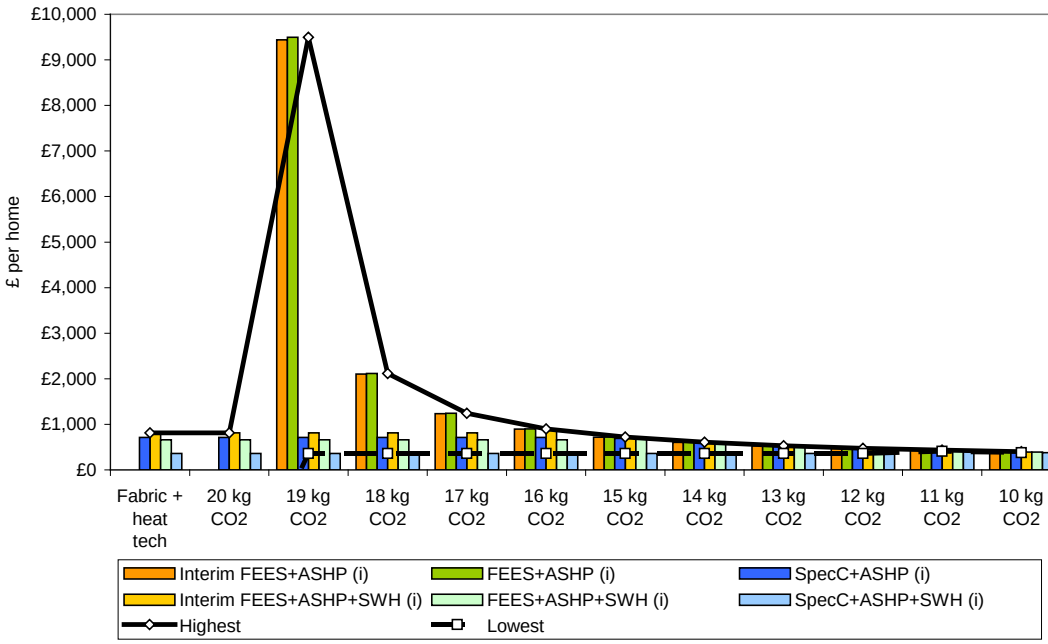
Fabric energy efficiency scenarios:

- Interim FEE
- FEES
- Spec C

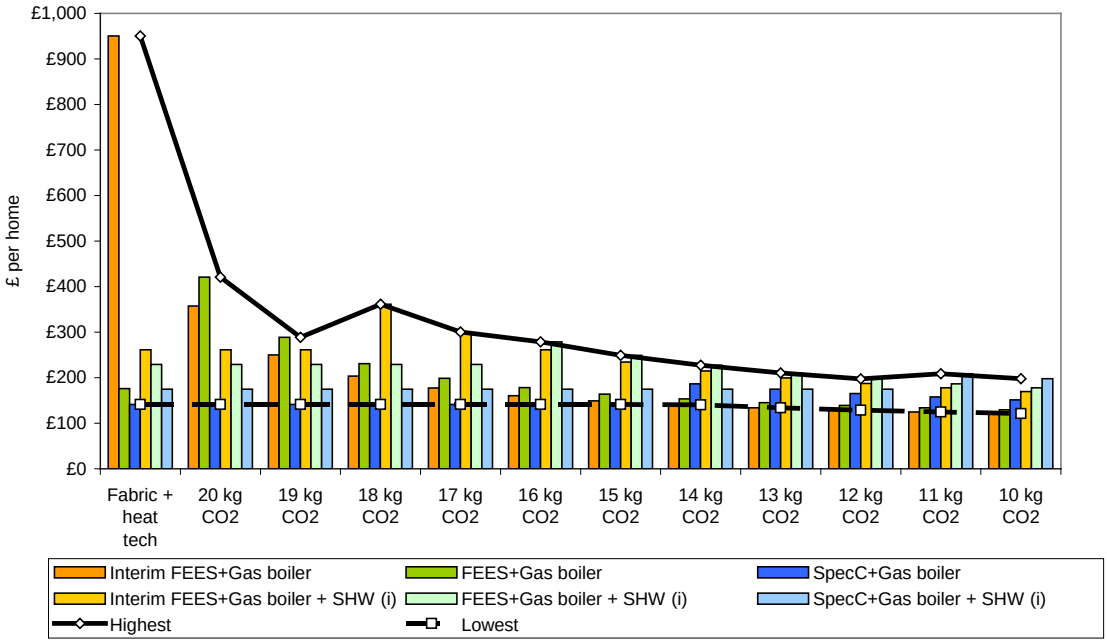
Mid-terrace house - Cost effectiveness (variable energy exclusing FiT / RHI)



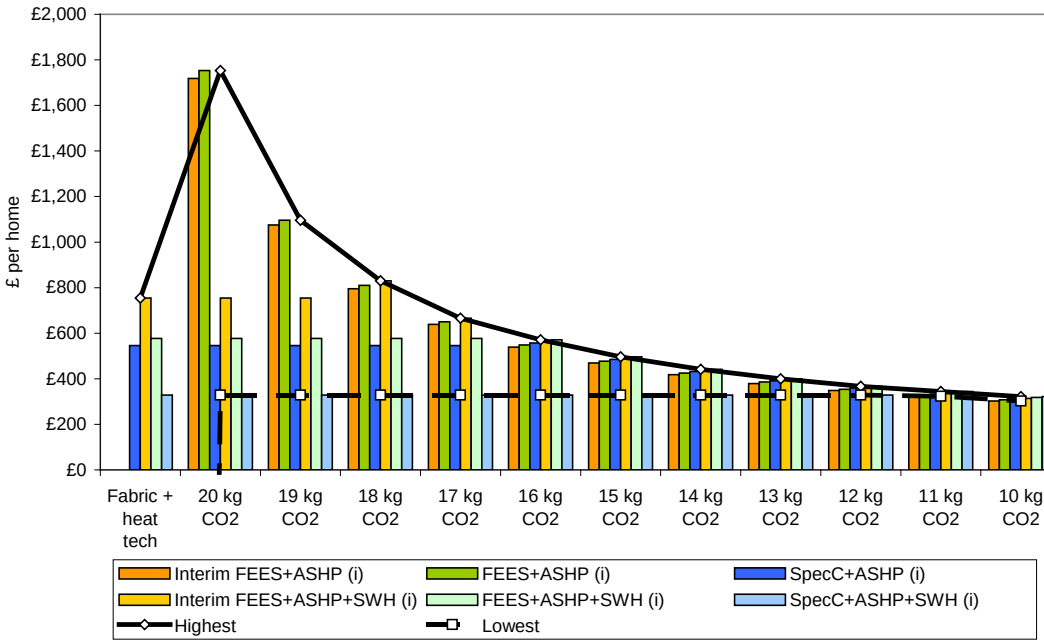
Mid-terrace house - Cost effectiveness (variable energy exclusing FiT / RHI)



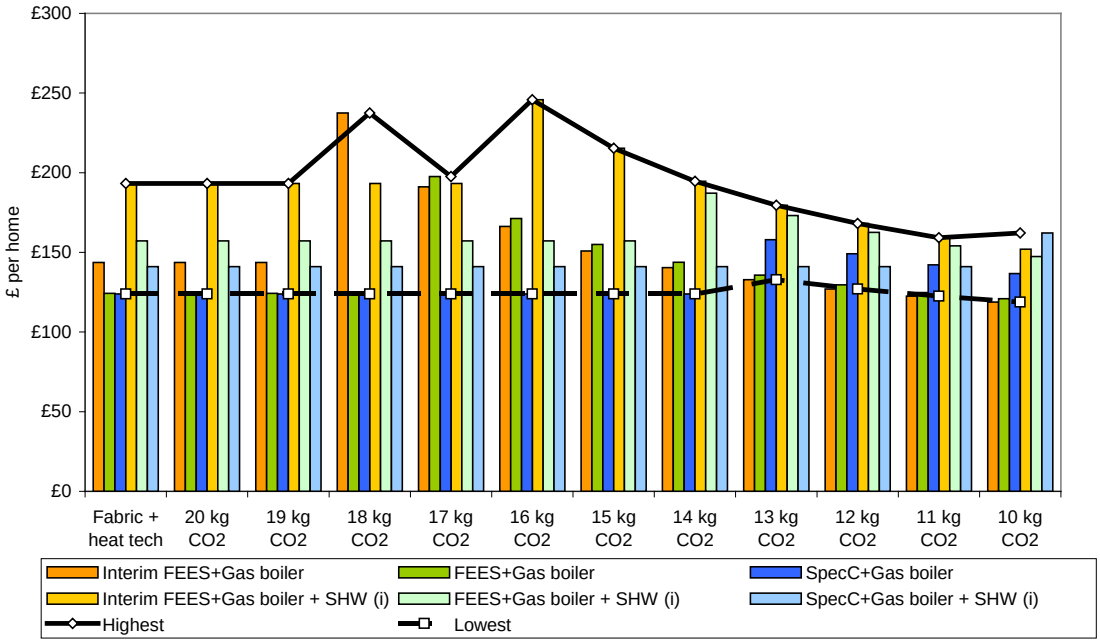
End of terrace house - Cost effectiveness (variable energy exclusing FiT / RHI)



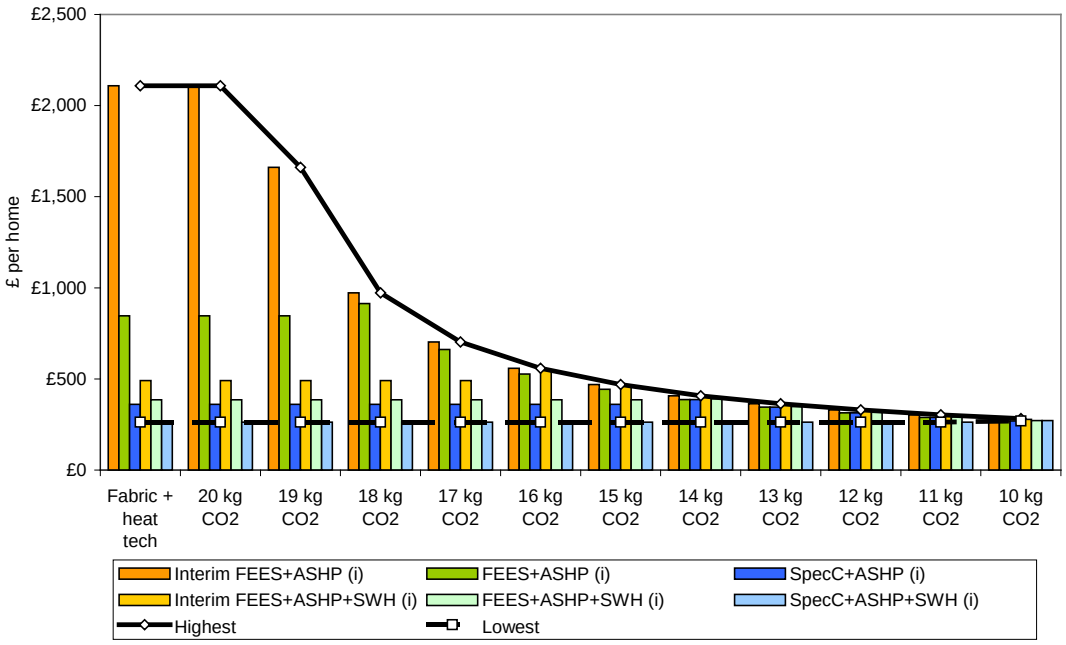
End of terrace house - Cost effectiveness (variable energy exclusing FiT / RHI)



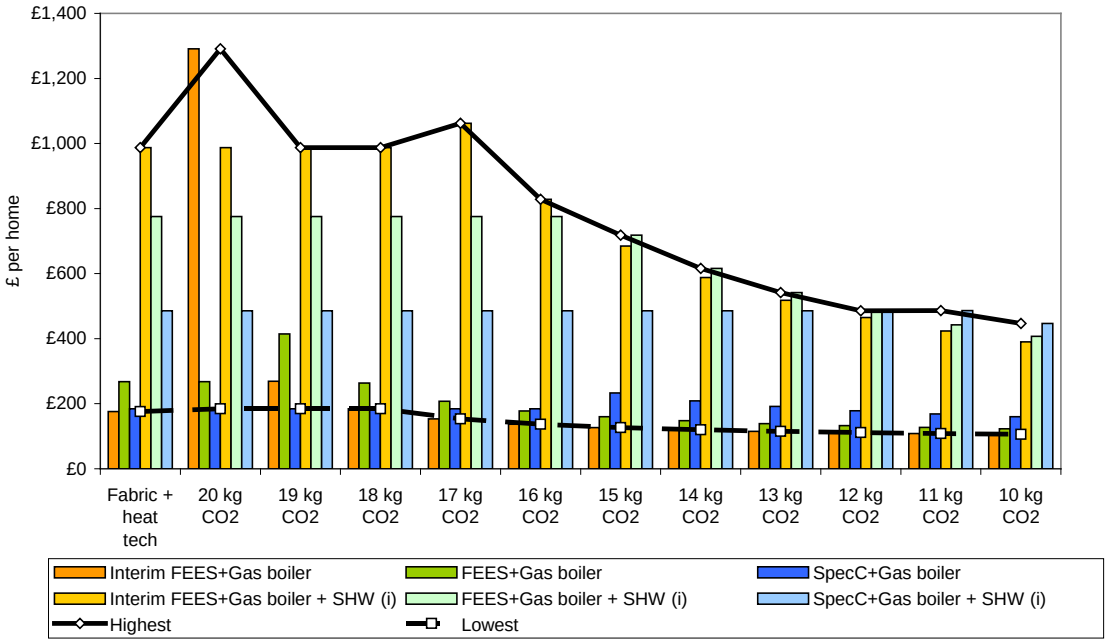
Detached house - Cost effectiveness (variable energy exclusing FiT / RHI)



Detached house - Cost effectiveness (variable energy exclusing FiT / RHI)



4 storey apartment - Cost effectiveness (variable energy exclusing FiT / RHI)



4 storey apartment - Cost effectiveness (variable energy exclusing FiT / RHI)