Transforming progress towards net zero homes in Charlbury

What have Cosy Homes Oxfordshire been doing?

Cosy Homes Oxfordshire (CHO) have been instructed by the Buildings Working Group of Charlbury Town Council to carry out research into the existing housing stock of Charlbury and, in light of the climate crisis and rising energy costs, to provide homeowners in Charlbury with information on how to make their homes more energy efficient and lower carbon.

CHO's work has included:

⇒ Mapping all houses in Charlbury (approximately 1,400) to establish their construction date and their built form (bungalow, flat, detached house, mid terrace etc).

⇒ Surveying 10 of the most common house types in Charlbury and using the Parity Projects software to analyse their current construction and identify the techniques and technologies that could be deployed to improve their energy and carbon performance.

⇒ Producing whole house plans for the 10 house types to demonstrate feasible retrofit measures and their implications in terms of cost, disruption and impact on fuel bills; carbon emissions and energy performance rating.

⇒ Compiling this overview report including housing type analysis and information on common retrofit measures.

⇒ Engaging with West Oxfordshire District Council (WODC) Planning Department to discuss how retrofit measures that homeowners might undertake could be sympathetically incorporated into the protected setting of Charlbury.

⇒ Undertaking town wide scenario modelling using the Parity Projects software to identify different pathways for Charlbury to achieve their net zero carbon goals. This part of the project is ongoing.

⇒ Engaging with local builders and contractors to develop the knowledge and skills base to establish an end-to-end supply/delivery chain which will provide residents with the opportunity to refurbish their homes towards net zero if they so wish. This part of the project is ongoing.

CHO's work is about analysis, information provision, community engagement and equipping homeowners with the knowledge of what they can do to their homes (both individually and at scale) to meet Charlbury's net zero carbon commitments.

What is Retrofit

Retrofit is works to a home to reduce its energy use and improve its comfort levels. These goals are achieved by increasing insulation levels; improving airtightness; installing low carbon services; and, where possible, generating energy on-site. Emissions from existing homes represent around 15-20% of UK carbon emissions so retrofitting also has a large part to play in the fight against climate change. The UK cannot meet its binding climate change targets without reducing the energy consumed by homes, both new and existing.

This report sets out a whole house approach to retrofitting some of the most common house types in Charlbury. The concept of the whole house approach is to look at people's homes holistically and consider their lifestyle, aims and budget. It adopts a phased, step-by-step approach to help avoid unintended consequences which can often result from tackling retrofit measures in isolation. For instance, sometimes simple insulation measures such as cavity wall insulation or loft insulation can result in mould growth if humidity and ventilation issues are not considered.

PAS 2035 is a British standard which sets out best practice guidance for retrofit. When looking for advice on retrofitting it's always best to use a PAS 2035 registered professional.

Much of the focus of the retrofit measures in this report is on reducing carbon emissions to show how Charlbury might reach its ambition to become a net zero carbon town. But the benefits of retrofit are multiple:

The structure of this report

First, we've identified the 10 most common house types in Charlbury and surveyed them:

Type A – the Green	Type B – Wychwood Paddocks	Type C – Woodfield Drive	Type D – Park Street	Type E – Nine Acres Lane
				
1970s, detached	1980s, detached	1960s, terraced	Pre-1900, traditional terrace	1950s, terraced

Type F – Hixet Wood	Type G – Sheep Street	Type H – Lee Close	Type I – Sandford Rise	Type J – Nine Acres Close
				
1950s, semi-detached	Pre-1900, listed terrace	1970s, semi-detached	1960s, detached bungalow	1960s, semi-detached bungalow

Second, for each house type we've identified:

⇒ *The key construction features*. For example, whether they have: solid or cavity walls; solid or suspended timber floors; timber or upvc windows etc.

⇒ *The typical metrics* of each house type, as it is now, according to our survey and the Parity Projects software. For example, the floor area; the estimated energy use per m^2 per year; the estimated carbon emissions per year; and the energy performance rating.

Third, we've set out the retrofit measures that may be appropriate for each house type, separated into 3 phases - minor, major and renewables. Each measure is set out according to cost, disruption and carbon cost effectiveness (the cost of a measure divided by the amount of carbon that it saves). For example:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Upgrade to digital heating controls	££	**	☺☺☺☺
Extract cavity wall insulation and refill	£££	**	☺☺☺
Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
External wall insulation	££££££	***	☺
New triple glazed uPVC windows	££££	****	☺☺

Fourth, we provide a phased retrofit example for each house type showing feasible retrofit measures; their estimated cost; and the impact that each phase could have on energy consumption, fuel bills and carbon emissions. For example:

Minor Measures	Estimated Costs	kWh/m^2	Fuel bill	tCO_2
Pre-retrofit	**Per Measure**	**146**	**£1,900**	**3.4**
300mm loft insulation	£1,900			
300mm loft insulation to inaccessible loft above porch	£1,700			
Separate off conservatory and stop heating it	£2,400			
Two new insulated doors	£5,000			
Ventilation measures	£2,000			
After minor measures		**134**	**£1,720**	**3.0**
Cost & % Improvement	**£13,000**	**8%**	**9%**	**11%**

Fifth, we give an estimate of how the energy performance rating of each house type could change if all the retrofit measures were instigated. For example:

Energy rating: **68 D** → **89 B**

Full whole house plans are also available for each house type. These provide more data on the impact of retrofit on the specific house type as well as graphs and detailed information on each retrofit measure:

The **final** part of the report gives useful information about the retrofit measures including links to further resources.

Important information about the analysis and the software

It's important to remember that although surveys were carried out to obtain as accurate information as possible about each house type, in most cases the actual levels of insulation and airtightness cannot be ascertained without more invasive analysis. This means that for most houses, assumptions have to be made about the fabric construction based on build dates.

The Parity Projects software relies on estimated, rather than actual, fuel bills and energy usage based on the nationally accepted methodology that underpins the calculations used for Energy Performance Certificates. In the whole house plans, some retrofit measures may appear to have a small impact on fuel bills or energy rating but in reality they may have a greater impact and also improve comfort levels and wellbeing, which cannot be measured.

House Typologies and Retrofit Measures

Set out below are details of the 10 most common house types in Charlbury; and the retrofit improvements that could be made to them to improve comfort levels, lower energy bills and reduce emissions.

Housing Type A - 1970s, detached house

Example: The Green, OX7 3QA

Key construction features:

- Detached, 3-4 bedrooms
- Bradstone or a combination of Bradstone & render
- Cavity walls originally without insulation but many have subsequently been filled
- Symmetrical roofs with overhanging eaves and lofts
- Solid uninsulated floors
- Integrated garages often converted into living accommodation and/or built above
- Some with bay or bow windows
- Some with porch extensions
- Double glazing - uPVC
- Chimneys – with closed or open flues

Typical metrics:

⇒ Floor area: between 80 to 100m^2
⇒ Energy use per year: 146 kWh/m^2
⇒ Carbon emissions per year: 3.4 tCO_2
⇒ Energy rating: 72 C

Key to Retrofit Improvement Measures:

Cost		
£	Less than £150	*
££	£150 - £1,000	**
£££	£1,000-£5,000	***
££££	£5,000-£15,000	****
£££££	£15,000-£25,000	*****
££££££	Over £25,000	
Disruption		
You will hardly notice ☺☺☺☺☺		
Briefly intrusive ☺☺☺☺		
Takes longer but you can live with it ☺☺☺		
Disruptive with installers in multiple rooms ☺☺		
Very disruptive – you may have to move out ☺		
CO2 cost effectiveness		
Pays for itself <£10/kgCO_2 £10-50/kgCO_2 £50-100/kgCO_2 >£100/kgCO_2		

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	☺☺☺☺
Check cavity walls for insulation	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Upgrade to digital heating controls	££	**	☺☺☺☺
Insulate and draught-proof loft hatch	££	*	☺☺☺☺☺
Install chimney sheep (if flue is open)	£	*	☺☺☺☺☺
Extract cavity wall insulation and refill	£££	**	☺☺☺
Make conservatory thermally separate (if present)	£££	**	☺☺☺
Increase loft insulation to 300mm	££	**	☺☺☺
Insulate bay window roof (if present)	£££	**	☺
Insulate porch roof (if present)	£££	**	☺

New insulated front door	£££	**	🙂🙂
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
External wall insulation	££££££	***	🙂🙂
New triple glazed uPVC windows	££££	****	🙂🙂

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	🙂🙂🙂🙂
Solar PV	££££	**	🙂🙂🙂

Phased retrofit example for Housing Type A - the Green

Minor Measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
Pre-retrofit	**Per Measure**	**146**	**£1,900**	**3.4**
300mm loft insulation	£1,900			
300mm loft insulation to inaccessible loft above porch	£1,700			
Separate off conservatory and stop heating it	£2,400			
Two new insulated doors	£5,000			
Ventilation measures	£2,000			
After minor measures		**134**	**£1,720**	**3.0**
Cost & % Improvement	**£13,000**	**8%**	**9%**	**11%**

Major measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After minor measures	**Per Measure**	**134**	**£1,720**	**3.0**
A++ triple glazed casement windows - uPVC	£13,000			
Extract CWI, refill and add external insulation to 1970s cavity walls	£21,000			
External insulation to cavity walls of 1990s extension	£10,400			
After major measures		**102**	**£1,380**	**2.3**
Cost & % Improvement	**£44,400**	**24%**	**20%**	**24%**

Renewables	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After major measures	**Per Measure**	**102**	**£1,380**	**2.3**
ASHP with radiator central heating and hot water	£20,000			
Solar PV – 3kWp, South East	£6,600			
After renewables		**24**	**£1,390**	**0.4**
Cost & % Improvement	**£26,600**	**76%**	**-1%**	**84%**
Cumulative cost & % improvement	**£85,100**	**84%**	**27%**	**89%**

Energy rating: **72 C** → **86 B**

Housing Type B - 1980s, detached house

Example: Wychwood Paddocks, OX7 3RW

Key construction features:

- Detached, 3-4 bedrooms
- Cotswold stone
- Cavity walls with integrated insulation (mineral wool batts)
- Symmetrical roofs – some with lofts, some with rooms-in-roof
- Suspended block and beam floors
- Some with integrated garages
- Some with single storey extensions
- Some with dormer windows
- Double glazing – timber or uPVC
- Chimneys – with closed or open flues

Typical metrics:

⇒ Floor area: 90 to 100m^2
⇒ Energy use per year: 156 kWh/m^2
⇒ Carbon emissions per year: 3.6 tCO_2
⇒ Energy rating: 71 C

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	☺☺☺☺
Cavity wall inspection	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Upgrade to digital heating controls	££	**	☺☺☺☺
Insulate and draught-proof loft hatch	££	*	☺☺☺☺☺
Install chimney sheep (if flue is open)	£	*	☺☺☺☺☺
Top up cavity walls, if suitable	£££	**	☺☺☺☺
Insulate suspended block & beam floor – using robot	££££	**	☺☺☺
Increase loft insulation from 75mm to 300mm	£££	**	☺☺☺
Insulate dormer window	££	***	☺☺☺
Insulate roof of single storey extension (if present)	£££	***	☺☺
New insulated door - timber	£££	**	☺☺
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Internal wall insulation (50mm) to 1980s cavity walls	££££££	*****	☺
New triple glazed timber windows	£££££	****	☺☺
Insulate room-in-roof (if present)	££££	****	☺☺

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	☺☺☺☺
Solar PV	££££	**	☺☺☺

Phased retrofit example for Housing Type B - Wychwood Paddocks

Minor Measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
Pre-retrofit	**Per Measure**	**156**	**£1,950**	**3.6**
Full multi zone digital controls	£650			
Top up insulation in 1980s cavity walls	£2,500			
300mm loft insulation	£2,100			
Two new insulated doors - external	£5,000			
Insulate suspended block & beam floor – using robot	£7,200			
Ventilation measures	£1,400			
After minor measures		**133**	**£1,700**	**3.0**
Cost & % Improvement	**£18,850**	**15%**	**13%**	**17%**

Major measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After minor measures	**Per Measure**	**132**	**£1,390**	**2.4**
A++ triple glazed casement windows - timber	£21,200			
Internal insulation (50mm) to 1980s cavity walls	£30,000			
After major measures		**117**	**£1,525**	**2.7**
Cost & % Improvement	**£52,000**	**12%**	**10%**	**10%**

Renewables	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After major measures	**Per Measure**	**117**	**£1,525**	**2.7**
ASHP with radiator central heating and hot water	£18,500			
Solar PV – 4kWp, South East	£7,400			
After renewables		**18**	**£1,260**	**0.3**
Cost & % Improvement	**£26,750**	**85%**	**17%**	**88%**
Cumulative cost & % improvement	**£98,600**	**88%**	**35%**	**92%**

Energy rating: **71 C** → **89 B**

Housing Type C – 1960s, terraced house

Example: Woodfield Drive, OX7 3SE

Key construction features:

- Terraced, 3 bedrooms
- Brick
- Cavity walls originally without insulation but many have been filled
- Symmetrical, low pitched roofs with lofts
- Solid uninsulated floors
- Some with integrated garages
- Some with porch extensions
- Some with rear extensions – often with flat roofs
- Double glazing - uPVC
- Chimneys – with closed or open flues

Typical metrics:

⇒ Floor area: between 80 to 95m^2
⇒ Energy use per year: 163 kWh/m^2
⇒ Carbon emissions per year: 2.9 tCO_2
⇒ Energy rating: 70 C

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	🙂🙂🙂🙂
Check cavity walls for insulation	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Upgrade to digital heating controls	££	**	🙂🙂🙂🙂
Insulate and draught-proof loft hatch	££	*	🙂🙂🙂🙂🙂
Install chimney sheep (if flue is open)	£	*	🙂🙂🙂🙂🙂
Extract cavity wall insulation and refill	£££	**	🙂🙂🙂
Increase loft insulation from 75mm to 300mm	££	**	🙂🙂🙂
Insulate porch roof (if present)	£££	**	🙂🙂🙂
Insulate extension flat roof (if present)	£££	**	🙂🙂🙂
New insulated front door	£££	**	🙂🙂
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
External wall insulation	££££££	***	🙂🙂
New triple glazed uPVC windows	£££££	****	🙂🙂

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	🙂🙂🙂🙂
Solar PV	££££	**	🙂🙂🙂

Phased retrofit example for Housing Type C - Woodfield Drive

Minor Measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
Pre-retrofit	**Per Measure**	**163**	**£1,750**	**2.9**
300mm loft insulation	£2,000			
Insulate inaccessible loft of extension	£1,600			
Insulate extension flat roof	£3,400			
Extract cavity wall insulation and refill	£2,700			
One new insulated door	£2,500			
Multi-zone digital controls	£630			
Ventilation measures	£1,400			
After minor measures		**134**	**£1,490**	**2.4**
Cost & % Improvement	**£14,230**	**18%**	**15%**	**17%**

Major measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After minor measures	**Per Measure**	**134**	**£1,490**	**2.4**
A++ triple glazed casement windows - uPVC	£15,000			
External insulation to 1960s cavity walls	£12,500			
External insulation to 1990s cavity walls	£5,200			
After major measures		**106**	**£1,240**	**1.9**
Cost & % Improvement	**£32,700**	**21%**	**17%**	**21%**

Renewables	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After major measures	**Per Measure**	**106**	**£1,240**	**1.9**
ASHP with radiator central heating and hot water	£18,500			
Solar PV – 3kWp, South West	£7,000			
After renewables		**25**	**£1,270**	**0.3**
Cost & % Improvement	**£25,500**	**77%**	**-2%**	**84%**
Cumulative cost & % improvement	**£72,750**	**85%**	**27%**	**90%**

Energy rating: **70 C** → **86 B**

Housing Type D – Traditional, pre-1900, terraced house

Example: Park Street, OX7 3PS

Key construction features:

- Terraced, 2-3 bedrooms
- Cotswold stone
- Solid walls (500mm)
- Symmetrical roofs often with rooms-in-roof and dormer windows
- Solid flagstone floor, uninsulated
- Some with modern rear extensions
- Single or double glazing (timber)
- Chimneys – with closed or open flues

Typical metrics:

⇒ Floor area: $58m^2$
⇒ Energy use per year: 181 kWh/m^2
⇒ Carbon emissions per year: 2.5 tCO_2
⇒ Energy rating: 68 D

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	☺☺☺☺
Boiler efficiency assessment	£	*	n/a
Upgrade to digital heating controls	££	**	☺☺☺☺
Install chimney sheep (if flue is open)	£	*	☺☺☺☺☺
Professionally draught-proof windows and doors	££	**	☺☺☺
Install secondary glazing	£££	**	☺☺☺
Insulate and draught-proof loft hatch	££	*	☺☺☺☺☺
Increase loft insulation to 300mm	££	**	☺☺☺
Insulate sloping ceilings of room-in-roof	£££	****	☺☺
Insulate extension flat roof (if present)	£££	**	☺☺☺
New insulated front door	£££	**	☺☺
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Internal wall insulation on street facing elevation	££££	*****	☺☺☺
External wall insulation on rear elevation	££££	***	☺☺☺
Solid floor insulation with or without underfloor heating	££££	*****	☺
New triple glazed timber windows	££££	****	☺

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	☺☺☺☺
Solar PV	££££	**	☺☺☺

Phased retrofit example for Housing Type D - Park Street

Minor Measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
Pre-retrofit	**Per Measure**	**180**	**£1,540**	**2.5**
Multi-zone digital controls	£570			
300mm loft insulation	£1,600			
Insulate sloping ceilings of room-in-roof	£4,600			
One new insulated door	£2,500			
Ventilation measures	£1,300			
After minor measures		**155**	**£1,360**	**2.1**
Cost & % Improvement	**£10,570**	**14%**	**12%**	**16%**

Major measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After minor measures	**Per Measure**	**155**	**£1,360**	**2.1**
Internal insulation to pre-1900s solid walls – street facing	£7,500			
External insulation to rear solid and cavity walls	£8,000			
Solid floor insulation with underfloor heating	£3,900			
A++ triple glazed timber sash windows	£15,400			
After major measures		**114**	**£1,080**	**1.6**
Cost & % Improvement	**£34,800**	**26%**	**21%**	**24%**

Renewables	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After major measures	**Per Measure**	**114**	**£1,080**	**1.6**
ASHP with enhanced existing radiator central heating and hot water	£18,000			
Solar PV – 2.1kWp, East & West elevations	£5,800			
After renewables		**23**	**£860**	**0.2**
Cost & % Improvement	**£23,800**	**80%**	**20%**	**86%**
Cumulative cost & % improvement	**£69,170**	**87%**	**44%**	**92%**

Energy rating: **68 D** → **88 B**

Housing Type E – 1950s, terraced house

Example: Nine Acres Lane, OX7 3QZ

Key Construction Features:

- Terraced, 3 bedrooms
- Pebbledash render
- Cavity walls originally without insulation but may have been subsequently filled
- Symmetrical roof with loft
- Suspended timber floors, some may have been converted to solid floors
- Double glazing – uPVC
- Some may have microbore heating pipes
- Chimney with closed or open flues

Typical Metrics:

⇒ Floor area: $100m^2$
⇒ Energy use per year: 191 kWh/m^2
⇒ Carbon emissions per year: 3.6 tCO_2
⇒ Energy rating: 66 D

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	☺☺☺
Cavity wall inspection	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Install chimney sheep (if flue is open)	£	*	☺☺☺☺☺
Remove gas heater (if present)	££	**	☺☺☺☺☺
Upgrade to digital heating controls	££	**	☺☺☺☺
Insulate and draught-proof loft hatch	££	*	☺☺☺☺☺
Increase loft insulation from 200mm to 300mm	££	**	☺☺
Insulate cavity walls	£££	**	☺☺☺☺
New insulated front door	£££	**	☺☺
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
External wall insulation on front and rear elevations	££££	***	☺☺☺
New triple glazed uPVC windows	££££	****	☺☺
Solid floor insulation	££££	*****	☺☺☺

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	☺☺☺☺
Solar PV	££££	**	☺☺☺

Phased retrofit example for Housing Type E - Nine Acres Lane

Minor Measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
Pre-retrofit	**Per Measure**	**191**	**£1,980**	**3.6**
Low energy lighting	£50			
Remove secondary gas heater	£350			
Increase loft insulation to 300mm	£2,000			
Cavity wall insulation	£1,500			
One new insulated door	£2,500			
Ventilation measures	£1,300			
After minor measures		**138**	**£1,480**	**2.6**
Cost & % Improvement	**£7,700**	**53%**	**25%**	**28%**

Major measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After minor measures	**Per Measure**	**138**	**£1,480**	**2.6**
External insulation to front and rear filled cavity walls	£15,500			
A++ triple glazed uPVC windows	£10,800			
Solid floor insulation	£7,500			
After major measures		**98**	**£1,130**	**1.8**
Cost & % Improvement	**£33,800**	**29%**	**24%**	**31%**

Renewables	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After major measures	**Per Measure**	**98**	**£1,130**	**1.8**
Air source heat pump with new radiator system	£27,000			
Solar PV – 3kWp, South East elevation	£6,500			
After renewables		**25**	**£1,250**	**0.3**
Cost & % Improvement	**£33,500**	**74%**	**-11%**	**83%**
Cumulative cost & % improvement	**£75,000**	**87%**	**37%**	**92%**

Energy rating: **66 D** → **86 B**

Housing Type F – 1950s, semi-detached house

Example: Council Houses, Hixet Wood, OX7 3SP

Key Construction Features:

- Semi-detached, 3 bedrooms
- Pebbledash render
- Cavity walls originally without insulation but may have subsequently been filled.
- Original, solid walled, single storey rear extension – with sloping ceiling
- Symmetrical roof either with loft or converted into room-in-roof (RIR)
- Both suspended timber and solid floors.
- Double glazing - uPVC
- Chimneys with closed or open flues

Typical Metrics:

⇒ Floor Area: 110m^2 (inc. RIR)

⇒ Energy use per year: 233 kWh/m^2

⇒ Carbon emissions per year: 5.2 tCO_2

⇒ Energy rating: 59 D

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	🙂🙂🙂
Cavity wall inspection	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Install chimney sheep (if flue is open)	£	*	🙂🙂🙂🙂🙂
Upgrade to digital heating controls	££	**	🙂🙂🙂🙂
Insulate and draught-proof loft hatch	££	*	🙂🙂🙂🙂🙂
Increase loft insulation from 200mm to 300mm	££	**	🙂🙂
Insulate cavity walls	£££	**	🙂🙂🙂🙂
Insulate sloping ceiling of rear extension	£££	***	🙂🙂🙂
New insulated front door	£££	**	🙂🙂
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
External wall insulation on all walls	££££££	***	🙂🙂🙂
Insulate suspended timber floors from below using robot	££££	**	🙂🙂🙂
Insulate room-in-roof	££££	*****	🙂🙂🙂
New triple glazed uPVC windows	££££	****	🙂🙂

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	🙂🙂🙂🙂
Solar PV	££££	**	🙂🙂🙂

Phased retrofit example for Housing Type F - Council Houses, Hixet Wood

Minor Measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
Pre-retrofit	**Per Measure**	**233**	**£3,000**	**5.2**
Multi-zone digital heating controls	£700			
Increase loft insulation	£1,700			
Insulate sloping ceiling of rear extension	£500			
One new insulated door	£2,500			
Ventilation measures	£1,500			
After minor measures		**188**	**£2,500**	**4.2**
Cost & % Improvement	**£6,900**	**19%**	**17%**	**19%**

Major measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After minor measures	**Per Measure**	**188**	**£2,500**	**4.2**
Cavity wall insulation with external wall insulation on cavity walls	£21,500			
External wall insulation on solid walls of rear extension	£7,300			
Suspended timber floor insulation	£6,800			
A++ triple glazed uPVC windows	£13,500			
After major measures		**116**	**£1,640**	**2.6**
Cost & % Improvement	**£49,100**	**38%**	**34%**	**38%**

Renewables	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After major measures	**Per Measure**	**116**	**£1,640**	**2.6**
Air source heat pump	£19,000			
Solar PV – 4kWp, SW and SE elevations	£7,400			
After renewables		**16**	**£1,250**	**0.3**
Cost & % Improvement	**£26,400**	**86%**	**24%**	**88%**
Cumulative cost & % improvement	**£91,700**	**93%**	**58%**	**94%**

Energy rating: **59 D** → **90 B**

Housing Type G – Traditional, pre-1900, terraced house (listed)
Example: Sheep Street, OX7 3RR

Key Construction Features:

- Terraced, 3-4 bedrooms
- Listed, in historic centre of Charlbury.
- Cotswold stone
- Solid walls (540mm)
- Rear extensions of a later date
- Symmetrical roofs often with rooms-in-roof (RIR) and dormer windows
- Solid floors, uninsulated
- Some with bay windows
- Timber sash or casement windows - often single-glazed (with secondary glazing) at the front; and some double glazing at rear.
- Chimneys – with closed or open flues

Typical Metrics:

⇒ Floor Area: 120m^2 (inc. RIR)
⇒ Energy use per year: 222 kWh/m^2
⇒ Carbon emissions per year: 4.7 tCO_2
⇒ Energy rating: 60 D

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	☺☺☺
Boiler efficiency assessment	£	*	n/a
Install chimney sheep (if flues are open)	£	*	☺☺☺☺☺
Upgrade to digital heating controls	££	**	☺☺☺☺
Insulate and draught-proof loft hatch	££	*	☺☺☺☺☺
Increase loft insulation to 300mm	££	**	☺☺☺☺
New insulated front door	£££	**	☺☺
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Internal wall insulation on all external walls	£££££	*****	☺☺☺
Insulate suspended timber floor above shop	£££	***	☺☺☺
Insulate room-in-roof	££££	*****	☺☺☺☺
New double/secondary glazing	££££	****	☺☺

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	☺☺☺☺
Solar PV	££££	**	☺☺☺

Phased retrofit example for Housing Type G - Sheep Street

Minor Measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
Pre-retrofit	**Per Measure**	**222**	**£2,800**	**4.7**
Low energy lighting	£50			
Multi-zone digital heating controls	£650			
Increase loft insulation – no access	£1,650			
One new insulated door	£2,500			
Ventilation measures	£1,400			
After minor measures		**190**	**£2,400**	**4.1**
Cost & % Improvement	**£6,250**	**14%**	**14%**	**13%**

Major measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After minor measures	**Per Measure**	**190**	**£2,400**	**4.1**
Upgrade room-in-roof – current insulation levels unknown	£7,100			
Internal wall insulation on solid walls	£8,250			
Internal wall insulation on timber frame walls	£5,000			
Combination of double glazing and A+ secondary glazing	£25,500			
After major measures		**103**	**£1,420**	**2.2**
Cost & % Improvement	**£48,850**	**46%**	**41%**	**46%**

Renewables	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After major measures	**Per Measure**	**103**	**£1,420**	**2.2**
Air source heat pump	£18,500			
Solar PV – 2kWp, south elevation	£5,700			
After renewables		**28**	**£1,460**	**0.4**
Cost & % Improvement	**£24,200**	**73%**	**-3%**	**82%**
Cumulative cost & % improvement	**£79,300**	**87%**	**48%**	**91%**

Energy rating: **60 D** → **84 B**

Housing Type H – 1970s, semi-detached house
Example: Lee Close, OX7 3SG

Key Construction Features:

- Semi-detached house, 3 bedrooms
- Brick walls
- Cavity walls originally without insulation but may have been subsequently filled
- Symmetrical rooflines, low pitched
- Solid floors, uninsulated
- Integrated garage, some may have been converted into living accommodation
- Double glazing – uPVC
- Chimneys with closed or open flues

Typical Metrics:

⇒ Floor Area: 87m^2 (inc. converted garage)
⇒ Energy use per year: 210 kWh/m^2
⇒ Carbon emissions per year: 4.0 tCO_2
⇒ Energy rating: 62 D

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	🙂🙂🙂
Cavity wall inspection	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Install chimney sheep (if flue is open)	£	*	🙂🙂🙂🙂🙂
Upgrade to digital heating controls	££	**	🙂🙂🙂🙂
New, insulated hot water tank	££	**	🙂🙂🙂🙂
Insulate and draught-proof loft hatch	££	*	🙂🙂🙂🙂🙂
Increase loft insulation from 100mm to 300mm	£££	**	🙂🙂🙂
Insulate inaccessible loft above garage conversion	£££	***	🙂🙂🙂
Insulate cavity walls	£££	**	🙂🙂🙂🙂
New insulated front door	£££	**	🙂🙂
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
External wall insulation on all walls	£££££	***	🙂🙂🙂
Insulate solid floors	££££	*****	🙂🙂
New triple glazed uPVC windows	££££	****	🙂🙂

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	🙂🙂🙂🙂
Solar PV	££££	**	🙂🙂🙂

Phased retrofit example for Housing Type H - Lee Close

Minor Measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
Pre-retrofit	**Per Measure**	**210**	**£2,260**	**4.0**
Low energy lighting	£80			
Multi-zone digital heating controls	£700			
New insulated hot water tank	£650			
Increase insulation in main loft to 300mm	£2,000			
Increase insulation in inaccessible loft above converted garage	£1,600			
Two new insulated doors	£5,000			
Ventilation measures	£1,500			
After minor measures		**170**	**£1,800**	**3.3**
Cost & % Improvement	**£11,530**	**19%**	**20%**	**18%**

Major measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After minor measures	**Per Measure**	**170**	**£1,800**	**3.3**
Cavity wall insulation with external wall insulation on cavity walls	£18,300			
Insulate solid floors	£9,000			
Triple glazed uPVC windows	£12,000			
After major measures		**104**	**£1,200**	**2.0**
Cost & % Improvement	**£39,300**	**39%**	**33%**	**39%**

Renewables	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO_2**
After major measures	**Per Measure**	**104**	**£1,200**	**2.0**
Air source heat pump	£19,000			
Solar PV – 2.5kWp, south elevation	£6,100			
After renewables		**30**	**£1,380**	**0.4**
Cost & % Improvement	**£25,100**	**71%**	**-2%**	**80%**
Cumulative cost & % improvement	**£75,930**	**86%**	**39%**	**90%**

Energy rating: **62 D** → **84 B**

Housing Type I – 1960s, detached bungalow
Example: Sandford Rise, OX7 3SZ

Key Construction Features:

- Detached bungalow, 3 bedrooms
- Bradstone
- Cavity walls originally without insulation but may have subsequently been filled
- Staggered, low pitched (20 °) roof with overhanging eaves and loft space
- Solid floors, uninsulated
- Integrated garages, some of which have been converted to living accommodation
- Double glazing - uPVC

Typical Metrics:

⇒ Floor Area: $55m^2$
⇒ Energy use per year: 211 kWh/m^2
⇒ Carbon emissions per year: 2.4 tCO_2
⇒ Energy rating: 67 D

Minor Retrofit Improvement Measures:

Minor fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Low energy lighting	£	*	🙂🙂🙂
Cavity wall inspection	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Insulate and draught-proof loft hatch	££	*	🙂🙂🙂🙂🙂
Increase loft insulation from 100mm to 300mm	£££	**	🙂🙂🙂
Extract cavity wall insulation and refill	£££	**	🙂🙂🙂
New insulated front door	£££	**	🙂🙂
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
External wall insulation on all walls	£££££	***	🙂🙂🙂
Insulate solid floors	££££	*****	🙂🙂🙂
New triple glazed uPVC windows	££££	****	🙂🙂

Renewable Improvement Measures:

Renewables	**Approx. cost**	**Disruption**	**CO_2 cost effectiveness**
Air source heat pump	£££££	****	🙂🙂🙂🙂
Solar PV	££££	**	🙂🙂🙂

Phased retrofit example for Housing Type I - Sandford Rise

Minor Measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO₂**
Pre-retrofit	**Per Measure**	**211**	**£1,320**	**2.4**
Low energy lighting	£50			
Increase loft insulation	£2,300			
One new insulated door	£2,500			
Ventilation measures	£1,300			
After minor measures		**196**	**£1,220**	**2.2**
Cost & % Improvement	**£6,150**	**7%**	**8%**	**8%**

Major measures	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO₂**
After minor measures	**Per Measure**	**196**	**£1,220**	**2.2**
Extract and refill cavity wall insulation and add external wall insulation	£12,000			
Solid floor insulation	£9,000			
A++ triple glazed uPVC windows	£10,500			
After major measures		**132**	**£880**	**1.5**
Cost & % Improvement	**£31,500**	**33%**	**28%**	**32%**

Renewables	**Estimated Costs**	**kWh/m²**	**Fuel bill**	**tCO₂**
After major measures	**Per Measure**	**132**	**£880**	**1.5**
Air source heat pump	£18,000			
Solar PV – 3.4kWp, south elevation	£7,000			
After renewables		**0**	**£300**	**0**
Cost & % Improvement	**£25,000**	**100%**	**66%**	**100%**
Cumulative cost & % improvement	**£62,650**	**100%**	**77%**	**100%**

Energy rating: **67 D** → **100 A**

Housing Type J – 1960s, semi-detached bungalow

Example: Nine Acres Close, OX7 3RD

Key Construction Features:

- Semi-detached bungalow, 2 bedrooms
- Bradstone or a combination of Bradstone and render.
- Cavity walls originally without insulation but may have subsequently been filled.
- Symmetrical roof with overhanging eaves
- Rear, flat roof extension
- Solid floors, uninsulated
- Double glazing - uPVC
- Chimneys with closed or open flues

Typical Metrics:

⇒ Floor Area: $65m^2$

⇒ Energy use per year: 230 kWh/m^2

⇒ Carbon emissions per year: 2.8 tCO_2

⇒ Energy rating: 63 D

Minor Retrofit Improvement Measures:

Minor fabric measures	Approx. cost	Disruption	CO_2 cost effectiveness
Low energy lighting	£	*	🙂🙂🙂
Cavity wall inspection	£	*	n/a
Boiler efficiency assessment	£	*	n/a
Install chimney sheep (if flue is open)	£	*	🙂🙂🙂🙂🙂
Insulate and draught-proof loft hatch	££	*	🙂🙂🙂🙂🙂
Increase loft insulation from 100mm to 300mm	££	**	🙂🙂
Insulate cavity walls	£££	**	🙂🙂🙂🙂
Increase flat roof insulation	£££	***	🙂🙂🙂
New insulated front door	£££	**	🙂🙂
Ventilation improvements	£££	***	n/a

Major Retrofit Improvement Measures:

Major fabric measures	Approx. cost	Disruption	CO_2 cost effectiveness
External wall insulation	£££££	***	🙂🙂🙂
Insulate solid floors	££££	*****	🙂🙂🙂
New triple glazed uPVC windows	££££	****	🙂🙂

Renewable Improvement Measures:

Renewables	Approx. cost	Disruption	CO_2 cost effectiveness
Air source heat pump	£££££	****	🙂🙂🙂🙂
Solar PV	££££	**	🙂🙂🙂

Phased retrofit example for Housing Type J - Nine Acres Close

Minor Measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
Pre-retrofit	**Per Measure**	**230**	**£1,720**	**2.8**
Low energy lighting	£50			
Increase loft insulation	£2,300			
Insulate flat roof of rear extension	£3,800			
One new insulated door	£2,500			
Ventilation measures	£1,300			
After minor measures		**202**	**£1,520**	**2.5**
Cost & % Improvement	**£9,950**	**12%**	**12%**	**11%**

Major measures	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After minor measures	**Per Measure**	**202**	**£1,520**	**2.5**
Cavity wall insulation with external wall insulation	£11,500			
Solid floor insulation	£10,300			
A++ triple glazed uPVC windows	£9,600			
After major measures		**128**	**£1,040**	**1.6**
Cost & % Improvement	**£31,400**	**37%**	**32%**	**36%**

Renewables	Estimated Costs	kWh/m²	Fuel bill	tCO_2
After major measures	**Per Measure**	**128**	**£1,040**	**1.6**
Air source heat pump	£17,500			
Solar PV – 2.5kWp, SE elevation	£6,100			
After renewables		**40**	**£1,300**	**0.4**
Cost & % Improvement	**£23,600**	**69%**	**-25%**	**75%**
Cumulative cost & % improvement	**£64,950**	**83%**	**24%**	**86%**

Energy rating: **63 D** → **81 B**

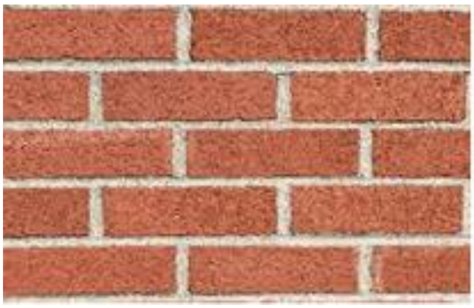
Information about different retrofit measures

In the house types above, the retrofit measures have been divided up into minor, major and renewables based on the estimated cost and the level of disruption involved. The next section of the report provides further information and advice on the different retrofit measures.

Understanding more about your house

Before deciding what retrofit measures to undertake it's a good idea to find out as much about the construction and insulation levels of your house as possible.

If your walls are made of brick it's possible to work out whether they are of solid or cavity construction. In general, walls built before 1920 tend to be solid, whilst those built after tend to be cavity, however, this is not a hard and fast rule. The brick pattern is the best way of identifying wall construction:


Cavity wall


Solid wall

If your walls are cavity then it's a good idea to find out whether they are filled with insulation. Cavity wall insulation became compulsory, at the point of construction, in the 1990s. Many cavity walls built before this date had no insulation but have subsequently been filled. Retrofitted cavity wall insulation (CWI) can be identified by small, holes at regular intervals in the cement pointing:


Evidence of CWI

With stone walls it is harder to determine whether they are of solid or cavity construction. The construction date can help. Looking at the walls in the loft spaces can also reveal whether the inner wall is built of concrete blocks which would indicate a cavity wall, faced in stone.

It's a good idea to identify and date the construction of any extensions. Some extensions are of timber frame construction (usually between 100-180mm thick) whilst houses built in the 1950s and 60s often had single storey, solid brick extensions at the rear. Looking up your house on the council planning portal can reveal building plans and help date extensions.

Finding out whether your house has suspended timber or solid floors on the ground floor will help determine the level of heat loss and the appropriate retrofit measure. In general, houses built before the 1950s tended to have suspended timber floors whilst after this date concrete became a more common floor construction material. A suspended timber floor has some 'give' in it when walked on but another good indicator is the presence of airbricks around the perimeter of the external walls, at ground level:

Victorian, ground floor airbrick

Some houses or extensions are built with suspended non-timber floors (concrete block and beam) often because of uneven ground levels or the need to maintain sub-floor ventilation for an adjacent suspended timber floor. These will also have airbricks.

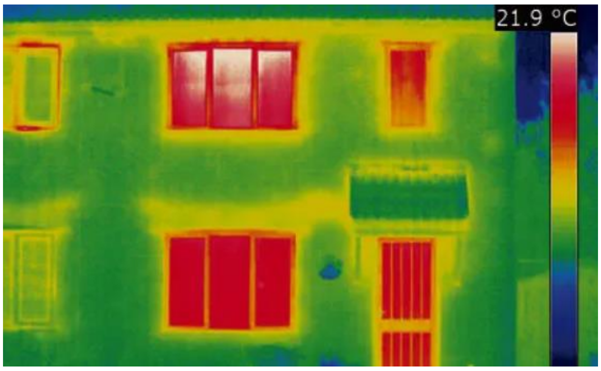
Undertaking further analysis

Often it is difficult to determine the insulation levels of a house and where the most heat losses might be occurring. There are various analysis techniques that can be used to understand how a building is performing and identify the most appropriate retrofit measures.

Borescope survey: this involves inserting a probe with a small camera on the end into inaccessible areas to identify the construction build up and whether insulation is present. It's particularly useful in determining whether cavity wall insulation has slumped; or the depth of a void beneath a suspended timber floor; or whether inaccessible loft spaces have sufficient insulation.

Borescope inserted into a cavity wall

Thermal image survey: this is where a thermal imaging camera visually represents the surface temperatures of different elevations and rooms of a house. They are useful in identifying cold spots and highlighting construction anomalies where building standards may not have been adhered to. Ideally, they are undertaken between September and April when the differential between outside and inside temperatures is at its greatest. It's also best that they take place early in the morning before the sun has a chance to warm facades.



Thermal image: The Guardian

Airtightness tests: these are used to determine the amount of uncontrolled air leakage through the gaps and cracks of a construction. When combined with a thermal image survey they can locate the path and source of draughts. They are very useful in determining the ventilation strategy for a house as part of the retrofit process.


Airtightness testing

Low and no-cost measures

The house typologies above demonstrate how costly and disruptive it can be to retrofit existing homes to zero carbon. There are, however, many free or low-cost measures which can be done with a DIY approach and these are a good way to begin the retrofit process.

West Oxfordshire District Council have published this list of low-cost ways to save energy in your home:

https://www.westoxon.gov.uk/media/ogspztnw/low-cost-ways-to-save-energy-in-your-home.pdf

Cherwell District Council have produced this guide to energy efficiency in traditional buildings:

https://www.cherwell.gov.uk/downloads/file/436/energy-efficiency-in-traditional-buildings

Examples of other low-cost retrofit measures include:

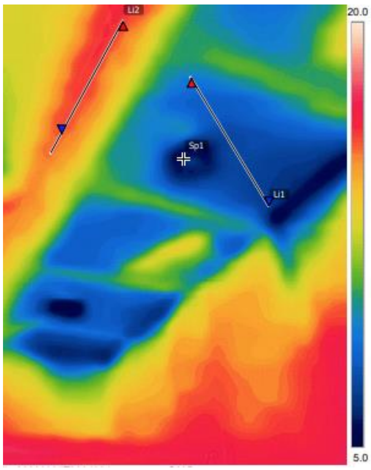
Open chimney flues. These can be a major source of heat loss and a low-cost way of reducing this is to install a chimney balloon or chimney sheep. They are inserted into the chimney, above the grate to temporarily block the flue. They are carefully designed to allow sufficient airflow up the chimney to prevent damp.

Chimney sheep

Chimney balloon

Draught-proofing and filling gaps in the construction fabric. Regularly checking seals around windows and doors and replacing them if they've failed can cut down heat losses. Also, any internal gaps between the window frames and the walls should be filled with decorator's caulk or mastic. Holes in external walls where pipes or electric cables enter the house can be filled using specialist airtightness foams and tapes. If you have exposed timber floors you can fill any gaps between the boards with caulk/sealant or thin strips of cork. With timber floors the junction where the floorboards and the wall meet can be prone to draughts. To limit these, skirting boards can be removed and airtightness tape applied at this junction, to be concealed when the skirting board is remounted.

Light fittings. Replacing incandescent and halogen light bulbs with LED equivalents can save a surprising amount on energy bills. The cost of LED light bulbs has fallen considerably over the years and there are affordable LED equivalent bulbs for most types of light fitting. Downlights in the ceilings of pitched roofs and in loft floors can be a source of draughts and reduce the effect of loft insulation. If downlights are LEDs, the back of them can be covered with a thermal light hood and then insulation can be placed around and over them.



Thermal image showing cold spots (darkest blue) around downlights in ceiling


Thermal lighthood covers. Credit: Loft Lid

Pipe lagging. All pipes that run within cold spaces including lofts, sub-floor voids, garages and storage areas should be lagged to reduce hot water heat losses and to prevent cold pipes freezing in sub-zero temperatures.


Pipes being lagged.

Loft insulation. Most lofts have some insulation but often it is only 100mm. Best practice is to have 300mm of insulation with the first layer laid between the joists and subsequent layers laid over them and at right angles to the layer below. For simple loft structures it is usually possible to install loft insulation as a DIY measure although it's important to ensure that any ventilation pathways at the eaves are not blocked. If you intend to store things in the loft then it's advisable to install a proprietary loft boarding system. This will be positioned with a small gap between the underside of the boards and the top of the insulation to allow any moisture entering the loft space to dissipate.

We have done some additional analysis on the benefits of loft insulation to demonstrate how important this retrofit measure is. Based on a roof area of 25m^2 and a pitched tiled roof with loft, the heat losses would be as follows:

Insulation level	Heat loss (W)
Uninsulated	1316
Insulated with 300mm rockwool but loft hatch left uninsulated	113
Insulated with 300mm of rockwool (including insulation and draught-proofing of loft hatch)	63

This demonstrates that not only is it important to insulate lofts but also not to forget about the loft hatch!

Highly insulated lofts are at greater risk of condensation because the temperature differential between the habitable and non-habitable areas of the house is increased. It's important to minimise the amount of warm, moist air entering the loft and this can be done by draught-proofing loft hatches, installing thermal light hoods over downlights and ensuring that moisture is effectively extracted from bathrooms, kitchens and utility areas. There should also be sufficient ventilation in the loft, above the insulation layers which can be achieved through eaves vents or roof tile vents.

Deeper retrofit measures

In this next section we deal with the deeper retrofit measures which involve varying levels of disruption and cost. For each measure we indicate whether it's a **minor measure**, with an estimated cost below £5,000 and not too much disruption, or a **major measure**, costing more than £5,000 and with greater disruption. With many of these deeper retrofit measures they should not be done as single, isolated measures (wall insulation, in particular) because they can change the internal conditions and affect the way that heat and moisture behave in the house.

Wall Insulation

In many people's homes, heat losses from the walls are one of the main contributors to energy bills. Wall insulation is essential if homes are to become zero carbon although for some houses it may not be an option.

There are 3 types of wall insulation:

- cavity wall insulation (CWI)
- internal wall insulation (IWI); and
- external wall insulation (EWI).

Deciding on which type of wall insulation is appropriate depends on the construction of the existing wall; the setting/aesthetics of the house; the improvement in heat loss being targeted; and budget. Houses can have a mixture of wall insulation, for instance: internal wall insulation at the front and external wall insulation at the rear. This is sometimes called hybrid wall insulation and is particularly common in conservation areas where the appearance of the front façade of the house cannot be altered.

Cavity Wall Insulation (minor)
This involves insulation, most commonly polystyrene beads set in resin, being injected into the cavity between the inner and outer walls of the house. One of the main advantages is that the insulation is hidden within the walls which means the internal/external appearance of the house is unchanged. The thickness of insulation is restricted by the depth of the cavity which means the heat loss improvements are also limited.

Many cavity walls have been filled but it is a good idea to check the coverage (either with a borescope or thermal image survey) because products such as urea formaldehyde and blown mineral wool can deteriorate or slump over time. Where CWI is no longer effective it's possible to have the old insulation extracted and the cavity refilled with new, high performance CWI.

Cavity wall insulation installation. Image: A&M Energy

Advantages:

- The internal and external appearance of the house remains unchanged which means no planning permission is required.
- It's relatively cheap even if existing insulation needs to be extracted.
- There is minimal disruption. CWI installation can usually be completed within a day.
- Services on the wall are unaffected.

Disadvantages:

- It is difficult to assess the coverage of insulation within the cavity.
- The improvement in the thermal performance of the wall is restricted by the depth of the cavity.
- Some cavity walls cannot be filled. For example, if they are too narrow (less than 50mm); filled with construction rubble; or if there is evidence of damp on the walls.

Things to watch out for:

- Companies that are cold calling to sell CWI. Always ensure that the installer can provide a guarantee from CIGA (Cavity Insulation Guarantee Agency).
- In general, applying external wall insulation to filled cavity walls presents no problem. Applying internal wall insulation to filled cavity walls is possible but usually requires moisture risk calculations to be undertaken.
- Access issues – most CWI hoses extend for approx. 15m from where the CWI vehicle is parked.

External Wall Insulation (major)

External Wall Insulation (EWI) gets applied to the outside of the house. Most commonly, it has a rendered finish but brick, stone or timber clad finishes are also possible. Depending on the type of insulation material used and the target performance of the walls, EWI can add 100-150mm to the thickness of the external walls.

Application of EWI. Image: Rockwool

Advantages:

- It offers the biggest opportunity for improvement in the performance of the walls.
- The internal decoration of the house is unaffected.
- The risk of moisture being trapped in the walls is low.

Disadvantages:

- For brick and stone properties EWI will change the external appearance of the house.
- EWI may require planning permission, especially in conservation areas and on listed buildings.
- Where existing walls sit directly on the property boundary or a public highway then EWI may not be possible.
- The cost of EWI can rise sharply if there are a lot of services (downpipes, gas pipes, electric cables, water taps etc) to be removed and refitted on the external walls.

Things to look out for:

- In terraced or semi-detached properties the most effective outcome is when adjacent houses have EWI applied at the same time.
- If the neighbouring property is not being insulated, a party wall agreement may be required.
- It may be necessary to extend the roof eaves of the house to cover the additional depth of the insulation.
- The ventilation of the house will need to be assessed and upgraded if there is insufficient fresh air or moisture extraction.

Internal Wall Insulation (major)

Internal wall insulation (IWI) is applied to the internal face of external walls. Sometimes it is necessary to return the IWI around the corner onto the side walls to avoid a cold bridge in the corner. IWI is most often applied to solid walls where, for aesthetic or heritage reasons, it is not appropriate to insulate the walls externally. On traditionally built walls it is best to restrict the thickness of the IWI to between 60 to 80mm because this reduces the risk of trapped condensation within the wall; and the thicker the insulation the greater the loss of floor area. In addition, in situ research has shown, that the first 40mm of wall insulation has the greatest impact on heat losses.

Internal wall insulation. Image: Ecological Building Systems

Advantages:

- The external appearance of the house is unchanged.
- It can be done on a room-by-room basis to accommodate budget and reduce disruption.
- In general, it does not require planning permission unless the house is listed.

Disadvantages:

- It's a disruptive measure and requires the room to be vacated and furniture moved.
- It reduces the size of the room.
- The cost of IWI can increase significantly if details such as cornicing, fitted furniture and skirting boards need to be removed and refitted.

Things to look out for:

- In solid walled houses we recommend the use of vapour permeable insulation materials (e.g. wood fibre or cork impregnated lime plasters). These lower the risk of moisture becoming trapped in the walls and causing damp.
- Ideally the wall insulation should extend upwards and downwards between the floor joists and the ceiling joists.
- If the external pointing of the house is in poor condition it should be re-pointed before IWI is applied.

- Correct detailing of IWI is important and it's recommended to seek advice from a retrofit professional.
- The ventilation of the house will need to be assessed and upgraded if there is insufficient fresh air or moisture extraction.

Roof and Ceiling Insulation

Flat roof insulation **(minor)**

Ideally flat roofs should be insulated from above the structure (a warm roof construction) but this requires the roof covering to be removed. For this reason, most people wait until their flat roof is showing signs of wear before insulating it. Sometimes flat roofs can be insulated from inside the room (a cold roof construction). This approach presents more moisture risk and it's important to find out how the flat roof is insulated before adding more insulation from below. New 'directional' membranes are available which manage the movement of moisture and are useful for insulating flat roofs where the overall height cannot be increased.

Advantages:

- If done from the outside this is usually a low disruption measure.
- It can lead to significant improvements in heat loss and comfort levels.
- Often bay windows have flat roofs above them and insulating them can mitigate cold and damp around the bay window area.

Disadvantages:

- Adding insulation from above raises the height of the flat roof which can cause complications if there are adjacent sloping roofs or windows.
- In a warm roof construction, deep fascia boards are necessary which can have a visual impact.

Things to look out for:

- Correct detailing of flat roof insulation is important and it's recommended to seek advice from a retrofit professional.
- Insulating flat roofs from below can create a condensation risk particularly if the flat roof is above a high humidity area such as a bathroom or kitchen.

Pitched roof or room-in-roof insulation (**major)**

Many houses have a room-in-roof (RIR) or an extension where the ceiling follows the contours of the roof rather than being flat e.g. a lean-to extension. Like a loft, these roof/ceiling elements must be insulated to restrict heat loss. Pitched roofs with sloping ceilings can be insulated in one of two ways.

If the roof is in poor condition the most effective and least disruptive option can be to remove the roof tiles and insulate between and over the rafters. With the use of insulated sarking board and appropriate membranes, it is possible to fully fill the rafters with insulation and achieve high levels of airtightness and performance. Most people only contemplate this option if their roof is nearing the end of its life because of the additional costs.

Advantages:

- Internal decoration of rooms is unaffected.
- No reduction in room height.
- This method can result in even coverage of insulation with minimal draughts and thermal bridging.

Disadvantages:

- Extra cost of scaffolding and replacement roof tiles.
- Best carried out outside of the winter months because it is weather dependent.
- Applying insulation on top of the rafters will increase the height of the roof, affecting gutters and other roof structures.
- This method will affect roof height relative to adjacent properties so it may not be suitable in terraced houses.

Things to look out for:

- Re-roofing (incorporating insulation) should be carried out by a contractor who understands the importance of airtightness and thermal bridging.
- A structural engineer may be needed to assess the condition of the roof.
- Planning permission may be required in a conservation area and/or listed building if the roof height is changing significantly.
- This is an excellent time to insulate any inaccessible loft spaces of the room-in-roof e.g. behind the knee walls.
- If you are thinking about external wall insulation, it may be sensible to extend the roof at the eaves so that it overhangs any future wall insulation.

Photo showing the area behind the knee walls of a RIR.
Semi-rigid insulation can be friction fitted between the upright timbers and held in place with either a membrane or timber battens.

The second option to insulate pitched roofs is to do it from below. This means the existing plasterboard is removed, and insulation is placed between and under the rafters. It is usually necessary to maintain a ventilation gap between the insulation and the roofing membrane which means that the rafters cannot be fully filled with insulation.

Advantages:

- Does not involve re-roofing.
- Lower cost option.
- Not weather dependent.
- May be the only option for terraced houses or where the external roof height cannot be raised.
- Suitable for lean-to extensions where lowering the internal room height is not a problem.

Disadvantages:

- The height of the room will be reduced by the thickness of insulation that is applied beneath the rafters.
- Involves replastering and redecoration.
- High levels of disruption.
- It can be harder to achieve even coverage of insulation particularly if the RIR has lots of nooks and crannies.

Things to look out for:

- Insulating sloping ceilings from below can create a condensation risk so consulting a retrofit professional is advised.
- A structural engineer may be needed to assess how much extra weight the rafters can withstand with the additional insulation.
- Ensure that the vertical knee walls are insulated as well as any inaccessible loft spaces around the RIR.

Regardless of whether insulation is applied internally or externally, we recommend using natural, rather than synthetic, insulation materials. Rooms-in-roof are liable to overheating (especially as the climate warms) and synthetic insulation materials, like PIR boards, can exacerbate this. Natural insulation materials, like wood fibre, have high decrement delay which is the time it takes heat to pass through a material.

Adequate ventilation in RIRs is also important as well as making sure excess moisture is extracted from the rest of the house to reduce the risk of condensation in the roof structure.

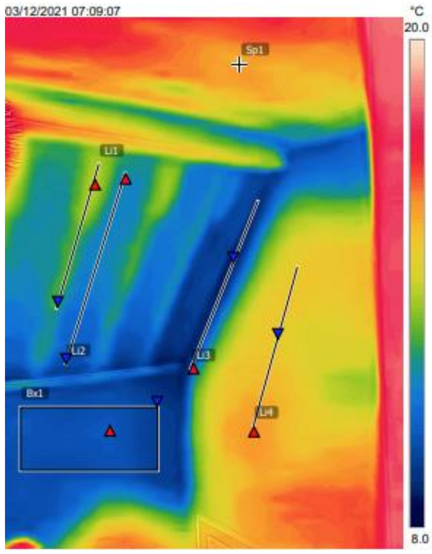
Dormer windows **(minor)**

Rooms-in-roof often have dormer windows:

Dormers are usually of a timber frame construction and their cheeks and roof should be insulated in a similar way to the main roof structure.

Skeilings **(minor)**

Skeiling is a construction term which refers to the sloping part of a ceiling, between the wall and the flat ceiling. They are often areas of 'forgotten insulation' and frequently show up as being cold in thermal imaging surveys:



Thermal image of a poorly insulated skeiling (sloping element of the ceiling)

Insulating skeilings is important, especially if the loft insulation is being improved, because poorly or uninsulated skeilings can be at risk of condensation and mould growth. Skeilings are tackled in much the same way as RIRs where the plasterboard is removed and insulation is applied between and beneath the rafters (whilst maintaining a ventilation pathway). If the skeiling is small then it may be possible to leave the existing plasterboard in place and apply insulation board on top but retrofit advice should be sought.

Floor Insulation

Suspended timber floors (**major)**

These were used in construction up to the 1950s. They typically consist of timber floor joists suspended above a void with ground below. To prevent the floor joists rotting, the void is ventilated front to back using airbricks. Suspended timber floors lose more heat than solid floors because of the cold air travelling beneath them. They also contribute to poor comfort levels because they create draughts.

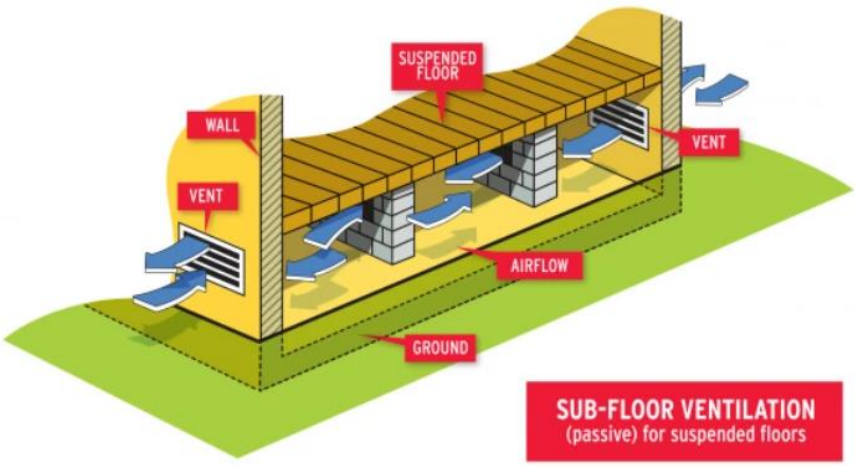


Image Credit: Environmental Protection Agency, Ireland

There are two ways of insulating suspended timber floors and both methods require good sub-floor ventilation and for the timber to be in a good condition.

One option is to lift the floorboards and to suspend semi-rigid insulation between the floor joists using a breather membrane to hold it in place and prevent the insulation falling into the void below. An airtight membrane is fixed above the floor joists before the final floor finish is installed.

Image: Ecological Building Systems

Advantages:

- This method can result in even coverage of insulation with minimal draughts and thermal bridging.
- It is possible to install underfloor heating at the same time.

Disadvantages:

- It's often not possible to salvage the existing floorboards either because they split on lifting or because of the time/expense involved in removing them for salvage.
- High levels of disruption including all furniture needing to be removed.
- Fitted furniture may have to be dismantled.
- Higher cost.

Things to look out for:

- Often the void beneath the floor joists is less than 20cm and will need to be dug out, adding to labour cost.
- This is a good measure to combine with internal wall insulation because the floor and wall insulation can be made continuous.
- Semi-flexible, breathable insulation materials such as rockwool or woodfibre are advisable.
- If your home is prone to flooding you should seek specialist advice before insulating the floor.

Occasionally there is enough accessibility from below to insulate the suspended timber floor without lifting it. This is often the case where there's an unheated basement or cellar. The big advantage of this is that disruption is minimised and the existing floorboards and skirtings can be left untouched. The method is the same as the one above with the airtight membrane installed first between and under the floor joists; then the insulation; and finally the breather membrane secured to the underside of the floor joists.

A second option for suspended timber floors is to use a robot to enter the void beneath the floor and spray insulation foam to the underside of the floorboards and the floor joists. Depending on the floor area, this method may cost less than £5,000 and be considered a minor measure.

Spray foam insulation using a robot. Image: Energy Saving Trust

Advantages:

- The existing floorboards and skirtings can be preserved.
- Low disruption – the room does not need to be emptied of furniture.
- Lower cost.
- Timing – works can usually be completed within one or two days.

Disadvantages:

- Underfloor heating cannot be installed.
- Some people are concerned about using synthetic spray foams which may have environmental consequences.
- Floorboards with spray foam are unlikely to be salvageable in the future.
- The spray foam is applied more thinly at the edges of the floor which is where the most heat tends to be lost.

Things to look out for:

- The sub-floor void needs to be deep enough to accommodate the robot.
- Adequate cross-ventilation is crucial and often additional airbricks need adding.
- Some floorboards will need to be lifted to create access for the robot.
- Think carefully about works that may involve lifting the floorboards in the future such as re-wiring and re-plumbing.

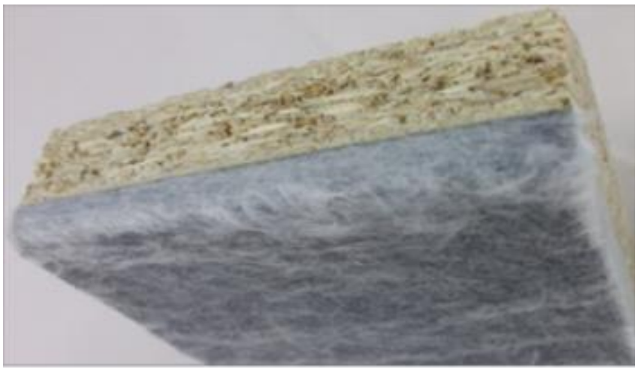
From the 1980s onwards block and beam floors became popular with mass house builders. They are a hybrid between a suspended timber and a solid floor where concrete blocks sit between pre-cast concrete beams with a void beneath. Many of them are uninsulated but they can be treated using all the methods described in this section.

Solid floors **(major)**

Solid floors can either be concrete (from the mid-19th century onwards) or flagstones sitting directly on top of earth or rubble. It is only in houses built after the mid-1990s where solid floors are insulated as standard. Insulating both types of solid floor involve high levels of disruption.

One option is to lay rigid boards of insulation on top of a damp-proof membrane, with plywood or chip board on top. However, this can raise the floor level by around 100mm. Thinner, high performing insulation such as aerogel or phenolic board can be used which is more expensive but can reduce the increase in floor level to 30-50mm. Whichever insulation is used above an existing solid floor, adjustments have to be made to doors, skirting boards, stairs, kitchen units, and radiators due to the increase in floor height.

Floating floor above rigid insulation boards
Image: AECB



Aerogel bonded to chipboard can be used to reduce the loss of floor to ceiling height. Image: AECB

Advantages:

- The existing concrete slab does not need to be broken up thereby reducing cost and disruption.
- Even small amounts of insulation can reduce the effect of a cold concrete slab and improve comfort levels.

Disadvantages:

- Thin, high performing insulation can be very expensive.
- Even a small increase in floor level can affect doors, skirting boards and the junction with the staircase.
- It's difficult to install sufficient insulation to enable underfloor heating to work effectively without breaking up the existing concrete.
- Loss of the thermal mass of the concrete (which can have a cooling effect in summer) because insulation is laid on top.

Things to look out for:

- Doors and skirting boards may need to be adjusted.
- If thicker insulation materials are used the height of the room will be reduced.
- This is a good measure to consider as part of other refurbishment works e.g. if you're having a new kitchen fitted.

Another option which is only viable as part of a large scale refurbishment, is to break up the existing concrete; dig out the floor; and incorporate insulation into a new concrete screed.

Advantages:

- Existing floor level remains the same.
- Underfloor heating can be installed at the same time.
- Thermal mass of the concrete is preserved because insulation sits within it.

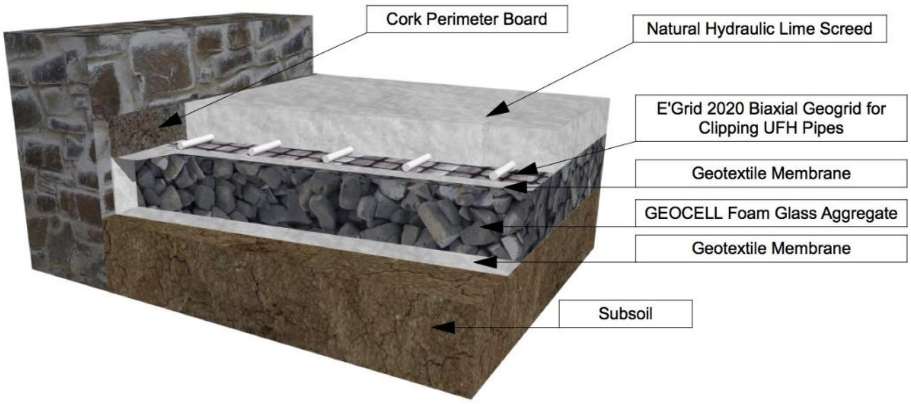
Disadvantages:

- Expensive.
- High levels of disruption and mess.
- Loss of embodied carbon as old concrete is disposed of and new concrete is laid.

Things to look out for:

- Structural engineers and other construction professionals may be needed if the foundations of the house are disturbed.
- Often problems can be unearthed and costs escalate.

Finally, where a solid floor is constructed of traditional flagstones laid directly on the ground it may be possible to lift them and add insulation below. Traditional solid floors have to be insulated with great care so as not to disturb the moisture balance of the house. Vapour permeable materials should be used and one system which is becoming popular is foam glass aggregate and natural lime screed, known as limecrete:



Limecrete floor with underfloor heating. Image: Mike Wye Associates

Advantages:

- Existing floor level remains the same so room height stays the same and doors don't need to be adjusted.
- Underfloor heating can be installed at the same time.
- Thermal mass is preserved because the insulation (foam glass) sits beneath the lime screed.
- Foam glass and lime are vapour open so the risk of moisture migrating from the floor to the walls is low.
- It may be possible to reinstate existing flagstones (dependent on their thickness) on top of the lime screed.

Disadvantages:

- Expensive.
- High levels of disruption and mess.
- Timing – lime screed requires a longer curing time than concrete.
- May not be suitable if a timber floor is laid on top of the lime screed which could lose moisture for many months.

Things to look out for:

- Structural engineers and other construction professionals may be needed if the foundations of the house are disturbed.
- Often problems can be unearthed and costs escalate.

- Damp problems must be resolved before embarking on this approach.

Windows and Doors

Windows (**major**)

Poorly insulated and installed windows can contribute significantly to a homes' heat losses They can also have a negative effect on thermal comfort levels especially if your seating is located near them. Poor performance windows can contribute to draughts and can be a cause of condensation and mould growth, especially in bathrooms and other high humidity areas.

If your windows are single glazed, metal-framed or double-glazed (dating from before 2002), it is advisable to replace them as there have been significant developments in window technology since then. The way windows are installed is crucial to their performance and there are many different types of expanding tapes which insulate and make airtight the junction between the window frame and the wall.

Triple glazing is suitable if you are aiming for a very high performing retrofit. They are more expensive than double glazed windows and it's important to weigh up the cost difference versus the better u-value.

Another important consideration with windows is the frame material. Most people are familiar with uPVC, timber and metal windows. UPVC has the benefit of being cheaper than other materials but it has high embodied carbon and often has a shorter lifespan than timber.

Timber windows are expensive but, for many people living in conservation areas or listed buildings, it is the only option. In the past, timber windows were either made from softwood or hardwood with the latter being significantly more expensive but having significantly better durability. Now, however, there is the option of engineered timber where small pieces of timber (either softwood or hardwood) are laminated together to produce a product which is structurally stable and much less likely to warp than solid timber. There's also a product called accoya which is created by 'pickling' pine to produce a timber that can withstand extreme weather and water ingress. Many modern, high performance windows are made from aluminium-clad timber or aluclad. These have an insulated timber core with an aluminum coating on the outside to protect the external face and remove the need for regular maintenance.

Listed Buildings and Conservation Areas

If your house is listed, you will need to apply for Listed Building Consent before replacing any windows. Local councils like to know the significance of a window before deciding whether it can be replaced, and this may mean that a historic building consultant needs to be engaged. Conservation officers are particularly interested in preserving historic glass because there is less and less of it around and it contributes to the aesthetics and history of a building.

Where windows are deemed historically significant the options for improving their efficiency may be restricted to using shutters or heavy curtains at night; or installing secondary glazing. Secondary glazing involves installing a second window on the interior side of the existing window and it can reduce heat loss by 50% as well as draughts. There are different types of secondary glazing many of which are extremely discrete and don't affect the opening mechanism of the window.

Secondary glazing. Image: Historic England

If your house is within a conservation area, as all houses in Charlbury are, replacing windows usually falls under permitted development providing the window is replaced on a "like for like" basis. We have had indications from West Oxfordshire District Council that permitted development rights should apply to new windows where the overall shape, colour and size of the window is similar to the existing. For peace of mind, it can be a good idea to apply for a certificate of lawfulness from the council when replacing windows in a conservation area.

Triple glazed timber sash window in a conservation area. Image: Green Building Store

Advantages:

- Reduced condensation and heat loss through the glass, particularly in bathrooms and high humidity areas
- Improved comfort levels especially when sitting near windows.
- Improved airtightness.
- Noise reduction.
- Improvement in the external appearance.
- Fairly low disruption – window installers are well trained in getting on with the job quickly.

Disadvantages:

- Expensive retrofit measure where the heat loss savings may not pay back the capital expenditure for many years (except where single glazing is being replaced).

Things to look out for:

- Always question your window installer about the method of installation – be wary if they rely on expanding foam to fill the gap between window and wall.
- If your house has cavity walls, ensure that the window installer understands the importance of closing the cavity if the frame of the window bridges it.
- Make sure you consider ventilation when replacing your windows. Under the latest building regulations, if you are replacing more than 30% of your windows, a ventilation strategy is required, to provide extraction from wet rooms (bathroom, kitchens, utility rooms) and fresh air supply to habitable rooms (bedrooms and living rooms). It's important to check whether trickle vents will be needed on your new windows before ordering them.
- Consider window replacement alongside wall insulation with the aim of ensuring the differential between the u-value of the windows and the walls is minimised. If you are planning cavity wall insulation and window replacement make sure that the new windows are installed before the cavity walls are filled.

Overheating

There is a balance between having enough glazing for sufficient levels of daylight and solar gain but not having too much, which can lead to overheating. If you have large amounts of glazing on a south or westerly aspect, it might be worth considering installing some shading in the form of a fixed awning; brise soleils; external shutters/blinds; or natural shading from shrubs or small trees.

Brise Soleil

Retractable awning

External Doors **(minor)**

Old external doors rarely have insulation and can be draughty. Replacing them with an insulated and draught-proofed one can help reduce heat loss and improve thermal comfort in both the hallway and the rest of the house. New external doors have the advantage of greater security because many of them have deadbolt locks which sit within the frame of the door rather than on the inner face. As with windows, there are different types of door material on the market including uPVC, timber, aluclad and composite (solid timber core faced with either uPVC, fibre glass or laminate).

From an energy efficiency perspective the most important thing to consider is whole door u-value and the quality of the draught-proofing seals. Many doors have glazed elements and it's a good idea to opt for triple glazing in this instance because the cost difference with double glazing shouldn't be too significant. Letter boxes reduce the performance of an insulated door so it's preferable not to have them incorporated within the door itself.

In a conservation area and/or listed property the same advice applies to external doors as to windows. It's possible to have bespoke, insulated timber doors made to match an existing door. If permission to change a door is not granted or your door is important to the aesthetics of the house then installing a thick, heavy curtain over the back of the door can reduce heat loss significantly.

Modern, triple-glazed, insulated timber door. Image: Green Building Store

Traditional insulated timber door. Image: Eksalta

Ventilation

A key part of any retrofit is improving and upgrading the ventilation. In fact, changes to the latest building regulations have meant that in most retrofit scenarios building control sign off can only be achieved if ventilation has been considered. Improving insulation levels has the knock on effect of improving airtightness and reducing uncontrolled air infiltration. This is a good thing from a heat loss perspective but it can have unforeseen, adverse effects, especially in relation to health and wellbeing, if a system of controlled air infiltration and stale, moist air extraction is not put in place. The market for ventilation products has expanded significantly in the last couple of years and the systems below are just a couple of examples of what's available on the market.

Decentralised ventilation **(minor)**

Decentralised ventilation is the most basic form of ventilation and it involves air inlets (either trickle vents on windows or wall vents) in the habitable rooms (bedrooms and living spaces) and extractor fans in wet rooms (bathrooms, kitchen and utility). With these systems the extract ventilation can either be intermittent (controlled, for instance, by either the light being turned on or manually switched such as a cookerhood) or continuous (where extractors are continuously extracting at a very low, quiet rate but automatically kick into boost mode when humidity levels rise).

Decentralised, humidity-controlled extractor from Greenwood Unity. Image: EpicAir

There are also through-wall extractors on the market which have heat recovery built into them, where heat from the extracted air is used to warm cold, incoming air. These are a possible single room solution in, say a bathroom, but they are not advised as a whole house ventilation solution. There's also the risk of the stale air being recirculated into the unit and back into the house.

Through wall heat recovery unit, Lo-Carbon Tempra range. Image: Vent Axia

Centralised ventilation **(major)**

There are various types of centralised ventilation system and in most cases they are a major retrofit measure because they require ducting and space for a large, centralised fan. The two main types of whole house ventilation system are either mechanical ventilation with heat recovery (MVHR); or demand control ventilation (DCV). Depending on the layout of the house and the scale of the retrofit, both systems can be disruptive to install, although DCV is often less disruptive than MVHR.

MVHR is the more expensive of the two systems and it can be an excellent solution in a deep retrofit scenario where high levels of airtightness and low energy consumption are targeted. MVHR systems extract warm, moist air from high humidity areas and use it to warm the supply of fresh air to bedrooms and living spaces. They also filter incoming air to remove pollutants such as particulates and pollen. High quality MVHR systems can recover 80-90% of their heat and can be very cost effective but to do this they need to operate within high levels of airtightness.

Paul MVHR unit. Image: Grand Designs

DCV is where a centralised, ducted fan unit extracts stale, moist air from the kitchen and bathrooms; and then separate smart wall vents open and close automatically (dependent on moisture levels) to deliver fresh air to bedrooms and living spaces. Although DCV systems do not recover heat they only supply and extract air when humidity levels dictate and so can be very energy efficient.

Aereco DCV fan & ducting located in loft. Image: Aereco

Renewables

Heat Pumps

A heat pump is essentially a fridge in reverse; instead of cooling it is used for heating. Heat is produced by squeezing heat out of the air or ground using refrigerants and a compressor. Depending on the type of heat pump and the external conditions it is possible to generate between 2 to 5 units of useful heat per unit of electricity.

Ground Source Heat Pumps (GSHP) extract heat from the ground and can reach higher levels of efficiency but they are more expensive to install and require either horizontal trenches to be dug or deep boreholes to be drilled. GSHP units need to be located in a small plant room e.g a garage, cellar or other outbuilding. Water source heat pumps are also an option but they can only be used next to a major body of water such as a river or lake.

Air Source Heat Pumps (ASHP) extract heat from the air, even when the air temperature is below freezing. To ensure that an ASHP can heat adequately and cost effectively it should be installed after or alongside measures that reduce the heat load of the house. Heat pumps should be installed by MCS approved installers who do a full heat loss calculation of the house to determine the size and make of the heat pump. It may be necessary to increase the size of radiators because heat pumps operate at a lower flow temperature than gas boilers and so a larger surface area is required to deliver sufficient heat. Unlike gas boilers which are programmed to come on at different times of the day, heat pumps operate most effectively when they are left to run continuously. Some consideration needs to be given to the location of the outdoor unit of an ASHP because they can create some noise and cool the surrounding air. In addition, if your house is within a conservation area, it is advisable that you consult with your local council before installing a heat pump, particularly if the outdoor unit will be visible from the street. If your house is listed, you will need to obtain Listed Building Consent before installing a heat pump.

Heat pumps are an effective way of reducing carbon emissions because the national grid is decarbonising at an increasing rate. But, depending on the type and efficiency of the boiler they replace, heat pumps can be cost neutral (and sometimes more expensive) in terms of running costs vis-à-vis mains gas, because electricity prices are 4 times more expensive than gas.

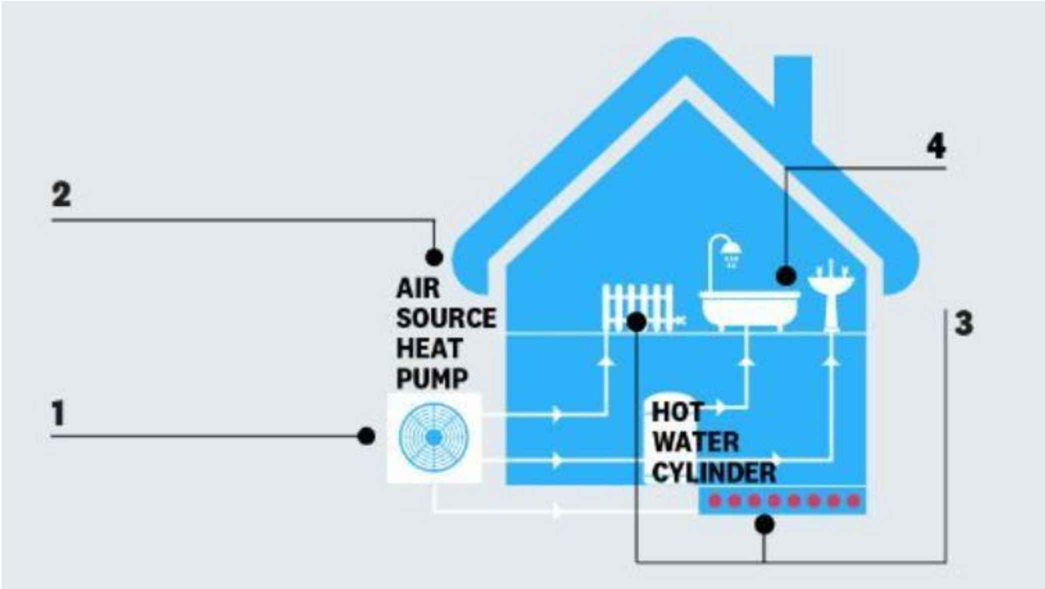


Image: Which

1. The air source heat pump absorbs heat from the outside air into a liquid refrigerant at a low temperature.
2. Using electricity, the pump compresses the liquid to increase its temperature. It then condenses back into a liquid to release its stored heat.
3. Heat is sent to your radiators or underfloor heating. The remainder can be stored in your hot water cylinder.
4. You can use your stored hot water for showers, baths and taps.

If replacing a combi boiler with a heat pump, it will be necessary to find a suitable place within the house for a new hot water cylinder that will be part of the ASHP system. Where a regular boiler is being replaced, the existing hot water tank often needs replacing with a heat pump compatible tank. There are also new smart hot water tanks which carry out volumetric heating (matching hot water heating to demand) and which are heat pump optimised.

Solar PV and solar thermal

For most people, on-site generation of power means solar PV or solar thermal. Generating power from wind is rarely available in urban areas and hydropower is dependent on a nearby water source and can be unreliable if water levels drop during hot, dry periods.

Solar PV provides a source of electricity which has multiple applications in the home. Solar thermal provides hot water which can be stored in the hot water tank for baths/showers or occasionally for use within the heating system. Although the conversion efficiency of solar thermal is high, it has fallen out of favour in recent years because homeowners prefer to use their roof space for solar PV for electricity rather than for hot water. Solar thermal requires on-going maintenance and also requires a more directly south facing roof. In addition, solar immersion devices which trigger the hot water tank to heat using immersion when there is excess home-generated electricity have made solar thermal less necessary.

Solar PV can be installed independently of other retrofit measures although it's a good idea to install battery storage with PV because the whole installation can attract 0% VAT whereas if a battery is installed separately then 20% VAT applies. In terms of orientation, the best location for solar PV is on a south, SW or SE facing roof but east/west orientations can also be viable. The cost effectiveness of solar PV is dependent on as much of the home-generated electricity being consumed on site which is where battery storage and smart car charging can be so beneficial.

Most solar PV installations are considered permitted development and generally will not need planning permission. However, solar PV on listed buildings will require listed building consent. In conservation areas, whether solar PV is considered permitted development is a little harder to deduce. There are indications for West Oxfordshire district council that if the solar PV is positioned to minimise the effect on the external appearance of the building and amenity of the area then it would be permitted development. However, this is unlikely to be the case on roofs fronting highways or on principle elevations and so planning permission should be sought.

Financial support for retrofit

Currently there is little by way of financial support for homeowners to help them with the cost of retrofit but this may change in the future as governments become more pressured to reduce carbon emissions. The schemes that are currently available are:

Energy Company Obligation (ECO). This is a scheme delivered through energy suppliers to help reduce the fuel bills and carbon emissions of customers in fuel poverty. It helps fund and deliver various retrofit measures.

Smart Export Guarantee (SEG). This is a scheme whereby energy companies pay homeowners who generate electricity, a small amount for the energy that they export to the grid. The payment levels are significantly lower than the old feed-in tariffs and only larger energy companies are obligated to pay them but this may change in the future.

Boiler Upgrade Scheme (BUS). This is a government grant, delivered through installers, to help homeowners with the upfront cost of installing a heat pump.

VAT. It's worth noting that since April 2022, retrofit measures that improve the energy efficiency of a home are exempt from VAT. This does not include window installations; secondary glazing; or ventilation measures but it does include draught-proofing, all forms of insulation; heat pumps; and renewable energy generation.

Definitions

Energy use (kWh/m^2): an estimate of the energy the home uses in a year for heating, lighting and cooling from all fuel sources e.g. the gas, the electricity, solid and liquid fuels etc. We then divide the total energy use by floor area to allow comparisons between homes. The energy figure does not include energy used for cooking, TVs, computers etc.

Carbon emissions (tCO_2): An estimate of the annual CO_2 emissions of the home for regulated energy use, based on carbon intensity values defined in SAP 10.2. This produces more accurate estimates for today's CO_2 emissions for electricity than the statutory 2012 value.

Carbon cost effectiveness: The estimated cost of a retrofit measure divided by the estimated kg of CO_2 per year that will be saved as a result of the retrofit measure.

Fuel bills (£): An estimate of the annual running costs for all regulated energy use based on fuel costs from Table 12 of the draft SAP 10.2 procedure.

Energy rating: A metric that aims to indicate energy use and fuel cost per unit of floor area, as recorded on EPCs and often referred to as an EPC or SAP score. The score is out of 100 (the higher the better) and it divides into performance bands A-G.

SAP (Standard Assessment Procedure) is a defined methodology used to create energy performance certificates for domestic buildings. SAP reviews and compares the amount of energy a house will consume when delivering a defined level of comfort and service provision. The software (Parity Projects) used to generate the calculations in this report uses the same SAP methodology but in some instances it augments some assumptions around price or CO_2 with more up to date assumptions.