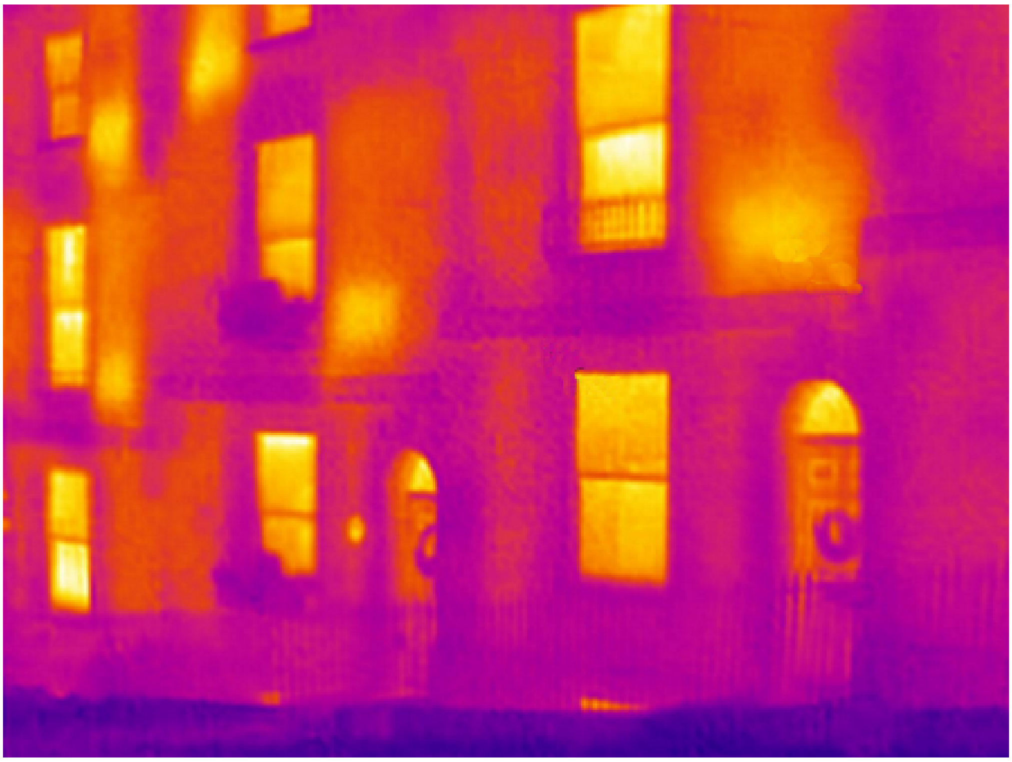
Thermal Camera Training Guide



This is a general guide on how to make the best use of a thermal imaging camera for reducing heating consumption in your home. It was developed to support the 3 thermal imaging currently available to borrow from community organisations in Bath:

- Transition Bath: Testo 875: Thermal Imaging Project | Transition Bath
- Share & Repair: Flir C5: Share & Repair (Bath Library of Things)
- Go Green Widcombe: Flir C3: Thermal Image Camera » Widcombe Association

Transition Bath also runs regular 2 hour training courses throughout the winter announced via its newsletter. We would encourage you to sign up for these courses as you will then be able to make the most from the camera you borrow.

How and then to make best use of a thermal imaging camera

Thermal imaging cameras work best when it is cold outside - below 10C, and provide better results when used inside rather than outside of a home.

Thermal imaging cameras detect differences in temperatures, and work best when there is a large difference between inside and outside temperatures, as a minimum we recommend a 10C difference, so for example 20C inside and 10C outside. This restricts useful usage of the cameras to the winter typically between November and March when the outside temperature is mainly below 10C. You will be able to see a lot more if for example the outside temperature is below 0C.

Other weather conditions which make thermal imaging more difficult:

1. wind: makes it difficult to see air leaks from house from the outside
2. sunshine: warms outside walls making it difficult to see leaks/missing insulation
3. rain: causes outside walls to appears colder than they are due to evaporation

All 3 of the above make imaging from inside a home more effective than outside a home.

It's important to heat your home for at least 2 hours before thermal imaging and to as high a temperature as possible to allow the heat to distribute evenly and to maximise the heat difference that can be seen.

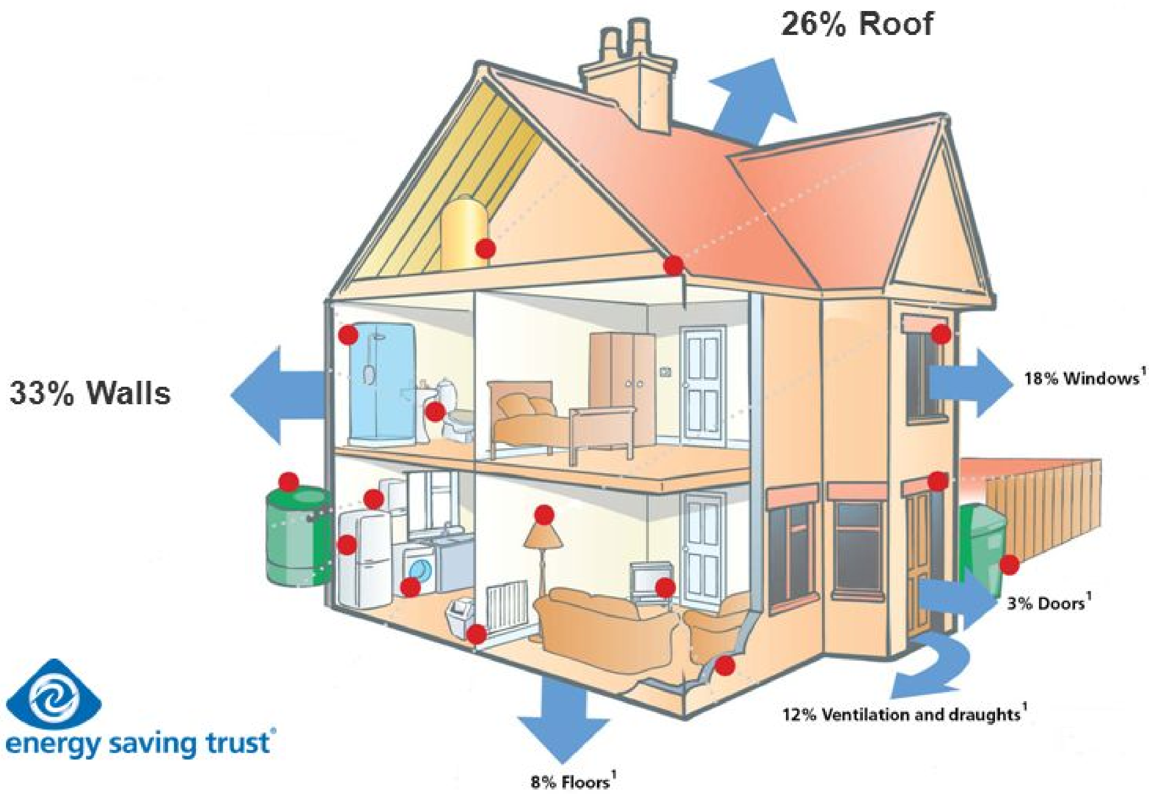
Heat losses and energy saving in homes

Where is energy used in a typical home?

Fuel	Appliances	Usage (kWh)	Cost	CO2 kg
Gas	Heating	9500	£665	1805
Gas	Hot water	2000	£140	380
Gas	Cooking	500	£35	95
Electricity	Appliances	3000	£900	540

How much can you save and a 'sense of the impact'?

It's important to understand and get a sense of proportion for where heat is lost from homes:



So for example when using the camera you might notice heat loss from your doors and consider replacing them but given doors might only account for 3% of your heating loss, reducing this by half might only save 1.5% of your heat loss and so may not be cost effective. Compare this with the benefits of insulating walls which might reduce their heat loss by 60% and your home's overall heating requirements by 20%.

Draughts

Draughts around doors and windows tend to show up well on thermal but might account for less than 3% of your homes overall heat losses. Heat losses from draughts can account for up to 15% of your home's heat losses but can come from multiple sources:

- windows and doors
- trickle vents above windows
- mechanical ventilation - e.g. in bathrooms and kitchens which allow draughts
- floors - particularly if you have an exposed timber suspended ground floors
- service exits - e.g. where water/drain pipes come in and out of the building
- inside ceilings where floor joists penetrate walls
- light fittings in upstairs ceilings
- loft hatches
- open chimneys, wood burners

Many of these sources don't show up well on a thermal imaging camera. A certain amount of 'air permeability' is good for homes to reduce damp and provide good air quality, but most homes in the UK have double the air permeability needed to provide a good environment, so most homes have opportunities to reduce draughts while still maintaining a good environment.

This webpage provides good advice on how to remediate draughts: https://www.homebuilding.co.uk/advice/draught-proofing and this for historic buildings: Tenements-Guide_Keeping-out-draughts.pdf (changeworks.org.uk)

Although reducing draughts may not have a significant impact directly on heat loss, draughts physiologically generally make people feel cold and cause higher thermostat levels in homes. So if significant draughts can be reduced it might then be possible to reduce thermostat temperatures. Every 1C reduction in thermostatic temperature reduces heating costs by about 1%.

Better boiler control

Perhaps the simplest change you can make to your home is to make your gas boiler more efficient by turning down the temperature to which it heats water, which allows the boiler to properly 'condense' and extract extra energy from the boiler's flue. You can improve the efficiency of the boiler by 10%, reduce your heating bill by up to 10% with less than 5 minutes work. This webpage explains what to do: https://moneysavingboilerchallenge.com/walkthrough/.

It is worth reviewing when your boiler turns on and off each day, reducing how long it's on for. Check whether you need radiators in unused rooms e.g. bedrooms.

Behaviour change

Behaviour change is often the most cost effective way of reducing energy costs and carbon emissions, heating costs reduce by on average 10% for every degree you lower the thermostat and thermostatic radiators valve temperatures. Do you know what the thermostatic temperatures are set to, can you lower them by wearing an extra layer of clothing in the winter?

Preparation for thermal imaging a property

Some suggestions:

- Make sure the camera is fully charged - this can take several hours
- Ensure the whole of the property has been heated above 20C for more than 2 hours beforehand
- Download all images from the camera and clear its memory before leaving
- Take a torch with you
- If you are visiting a strangers home, please let a third party know

Optimum Weather Conditions to Good Thermal Imagery

Thermal imaging cameras work best when there is a big temperature difference between the inside and the outside of a property. Most thermal imaging camera manufacturers recommend the following:

- Temperature difference between inside and outside of property > 15C
  - This typically means an outside temperature of < 5C
  - And, an inside temperature of 20C+, and the **heating should have been on for about 2 hours beforehand** so temperatures even out in the property
  - You are likely to see twice as much detail on the camera if the outside temperature is at 0C compared with 10C
- Wind speed < 12 mph for external photography
  - This avoids hot air leaking out of the building being blown away too quickly
  - There may however be some benefit of high winds for internal work as it might increase draughts
- No rain, for external photography
  - First of all you should assume the camera is not waterproof
  - Secondly damp surfaces tend to distort the results
- Lack of recent sun for external photography, hence evenings are best
  - Sun heats up stone/brick surfaces giving false results

We may find however that useful results can be gained outside these ‘optimal conditions’, some experimentation is required.

Resources

https://www.changeworks.org.uk/sites/default/files/Energy_Heritage.pdf

https://www.cse.org.uk/downloads/reports-and-publications/energy-advice/insulation-and-heating/warmer_bath_june2011.pdf

Energy at Home

What is the UK Government’s ECO+ scheme? - Energy Saving Trust

Example Images and How to Interpret Them

The remainder of the document contains some example images, which are common themes you should see when surveying homes.

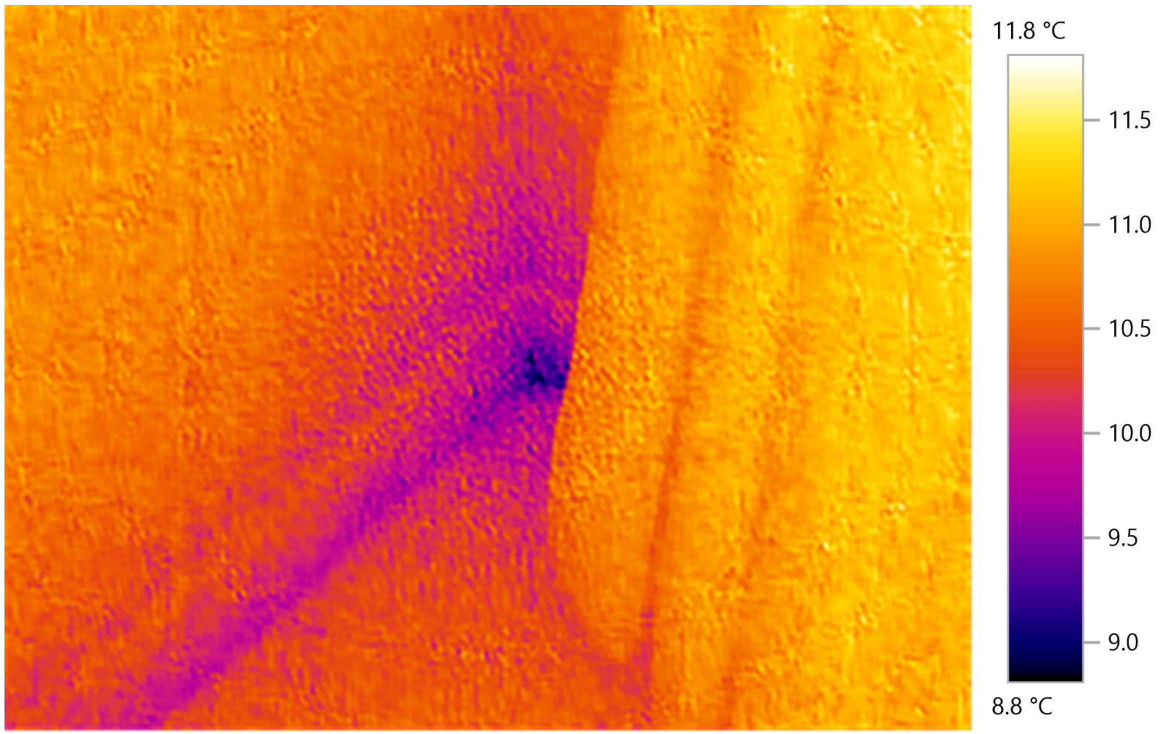
Generally heat loss is split into 2 categories:

- '**Fabric Losses'** : fabric losses occur from conduction through solid objects and are reduced by increasing insulation
- '**Air permeability'**: more commonly known as '**draughts'** are where air leaks in and out of a house and are typically improved by sealing holes and gaps

Colours:

Generally thermal imaging cameras show cold as a blue colour and red as a hot colour. So you are looking to reduce cold elements in blue when looking from inside a home, and hot elements in red when looking from outside -both of which represent heat leakage in the wrong direction.

False positives:

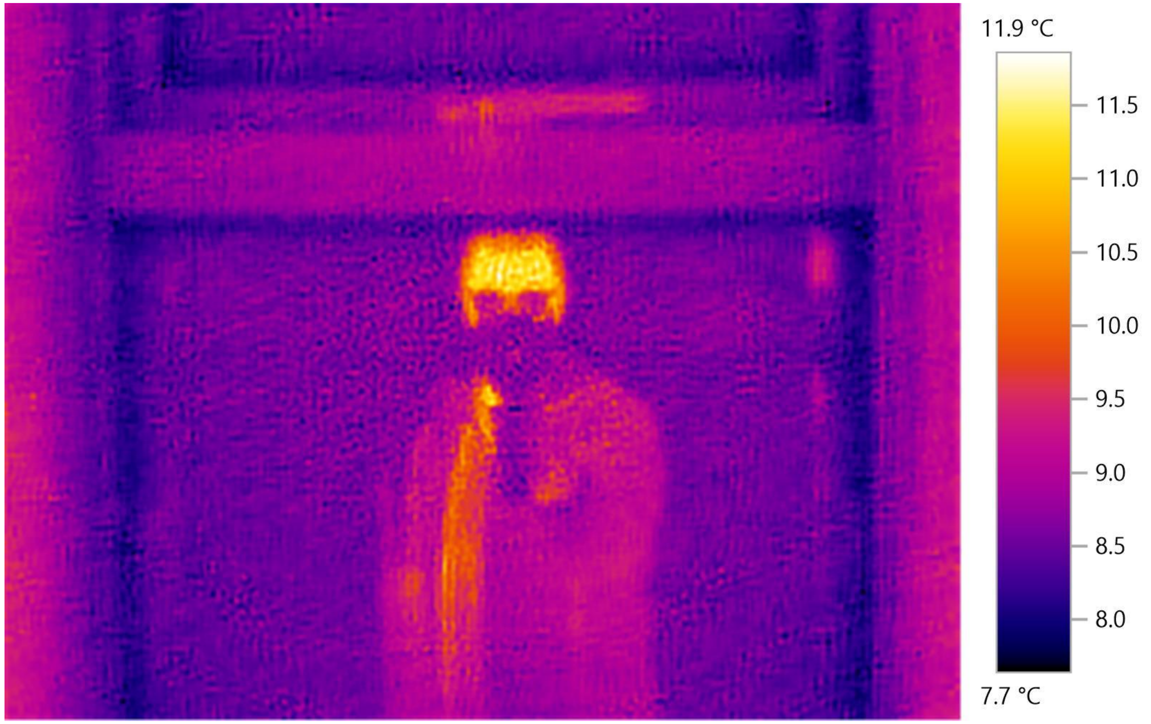


Observation: Air in corners of rooms, under cupboards which is ‘trapped’ and can’t easily move doesn’t get heated like the rest of the air in a room appears blue on thermal images. This is known as a ‘false positive’ - something which appears to be a heat loss but isn’t.

Inexperienced thermal imagers need to be aware of this issue and not jump to conclusions about the corners of their rooms lacking insulation.

Remediation: there is nothing to be done about this, in most circumstances you need to be aware of the issue but ignore it as it is an artefact of thermal imaging and not something wrong with your home which needs addressing. Generally if the home has been heated for a long period (> 2 hours) in advance of thermal imaging then this effect will be reduced but not completely eliminated.Very occasionally it may be a ‘real’ issue i.e. a cold patch or thermal bridge in the corner of a room.

Emissivity and reflectivity:



Observation: much like in the visible world different materials reflect differently, this can make it difficult to use a thermal imaging camera. Glass and metal surfaces in particular reflect heat, and so you can often see your own reflection when trying to thermally image a window inside making it look hot, or the temperature of the sky (typically below -20C) when imaging outside making upstairs windows look very cold.

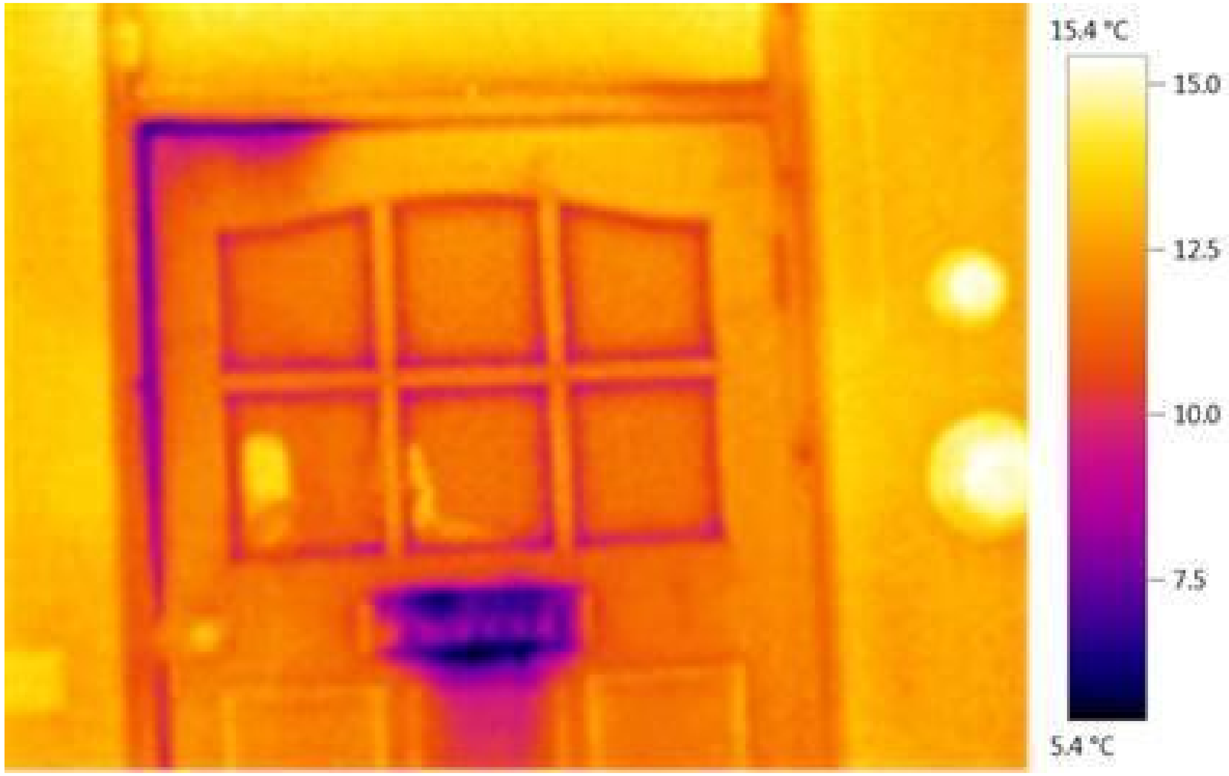
Plastic and tile surfaces also absorb and emit heat quite differently from other materials making it almost impossible to do good thermal imaging analysis in bathrooms and kitchens. The mix of these differing materials makes understanding UPVC windows very difficult for example. Further explanation of emissivity.

Remediation: be careful when imaging glass, metal, tile and plastics as they can provide a false impression. Kitchens and bathrooms often don;t work well with a thermal imaging camera.

You can improve things a little by using the camera at an oblique angle so a reflection of a cold or warm heat source doesn't reflect back to the camera.

Moving closer to an object to mask off material or heat sources causing problems, masking them out of the image can also help.

Doors

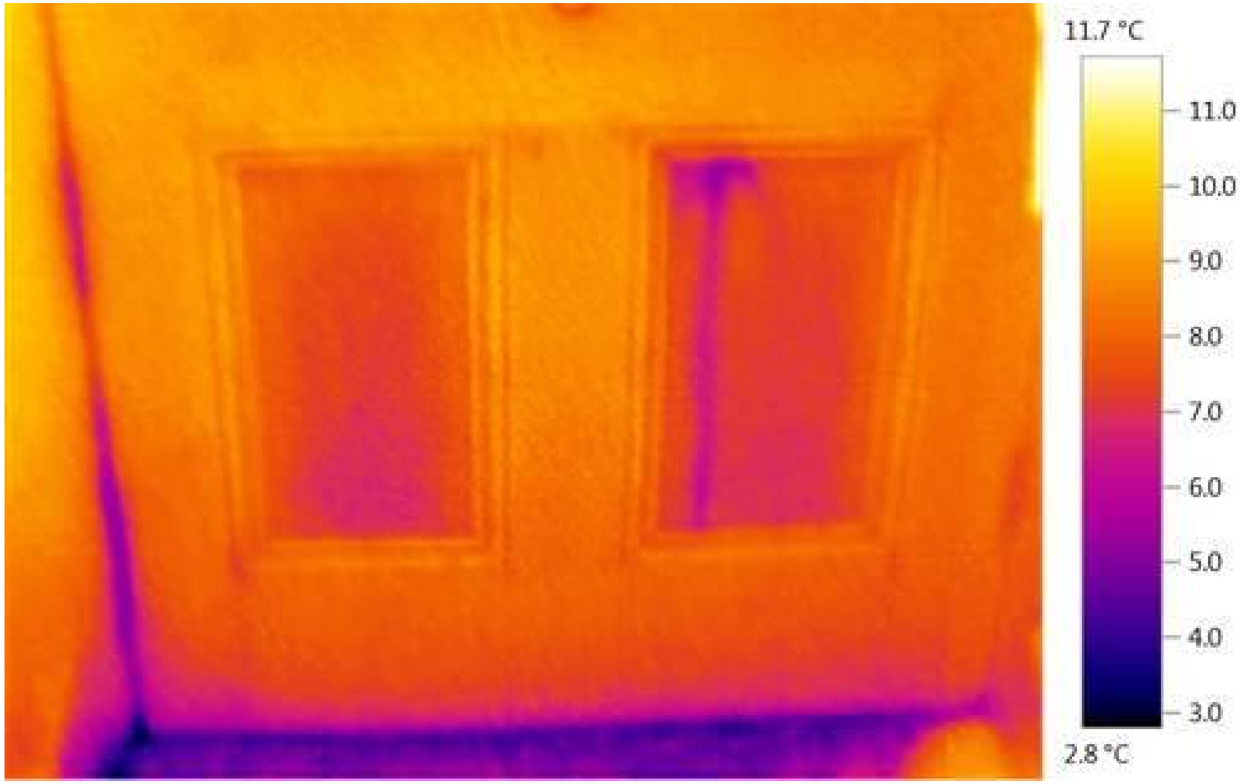


Observation: Badly sealed and insulated doors commonly show up when doing thermal imaging surveys and they are easy to fix. This image shows a door with gaps and therefore draughts around the top of the door and the letter box.

Remediation: could include:

- fixing draught striping which you can buy from the local hardware store around the end of the door
- fixing a letterbox draught excluder
- installing a thermal curtain
- placing a draught excluder at the bottom of the door (which you can buy or make for yourself out of old material)
- fix an additional security bolt to the door if it is caused by a warped wooden door

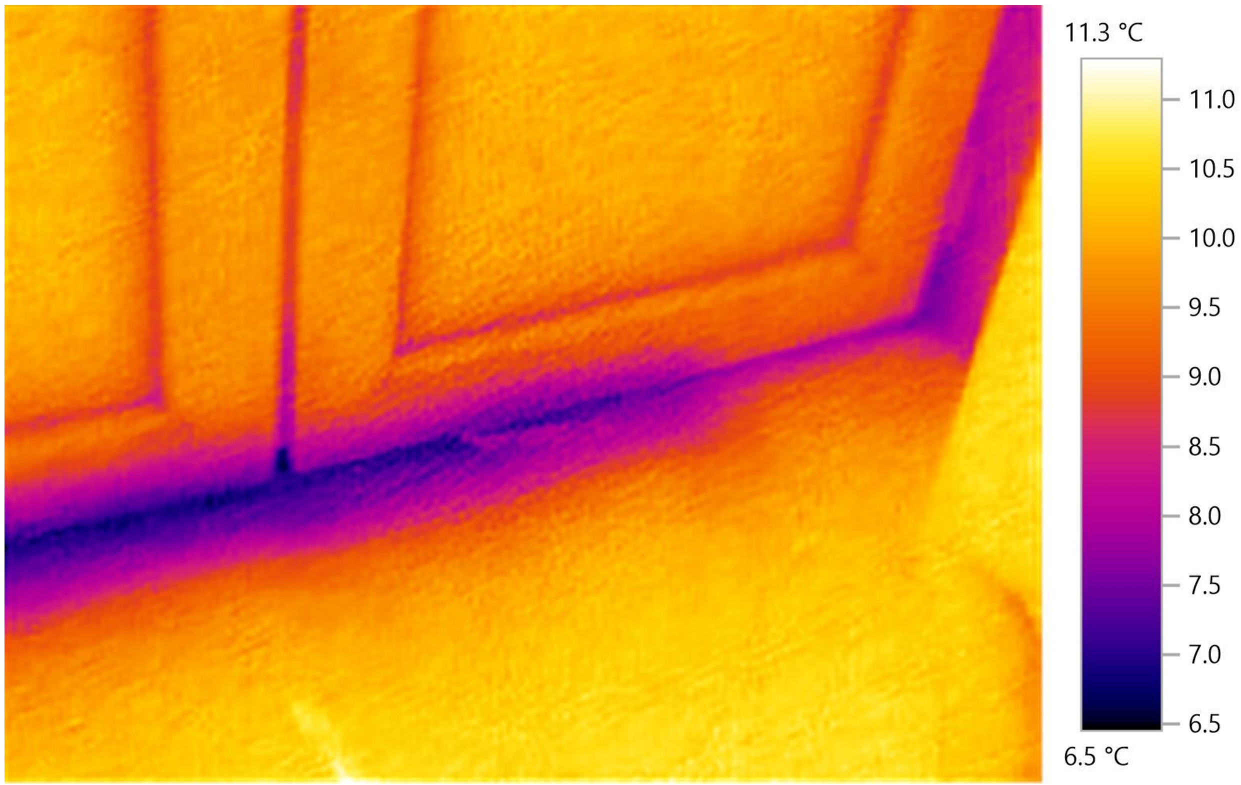
Energy savings: if fixed my reduce your heat losses by 1% to 3%



Observation: The front door could do with draught stripping.

There is also a split in the panel which could be reaired or a thin layer of insulation inserted

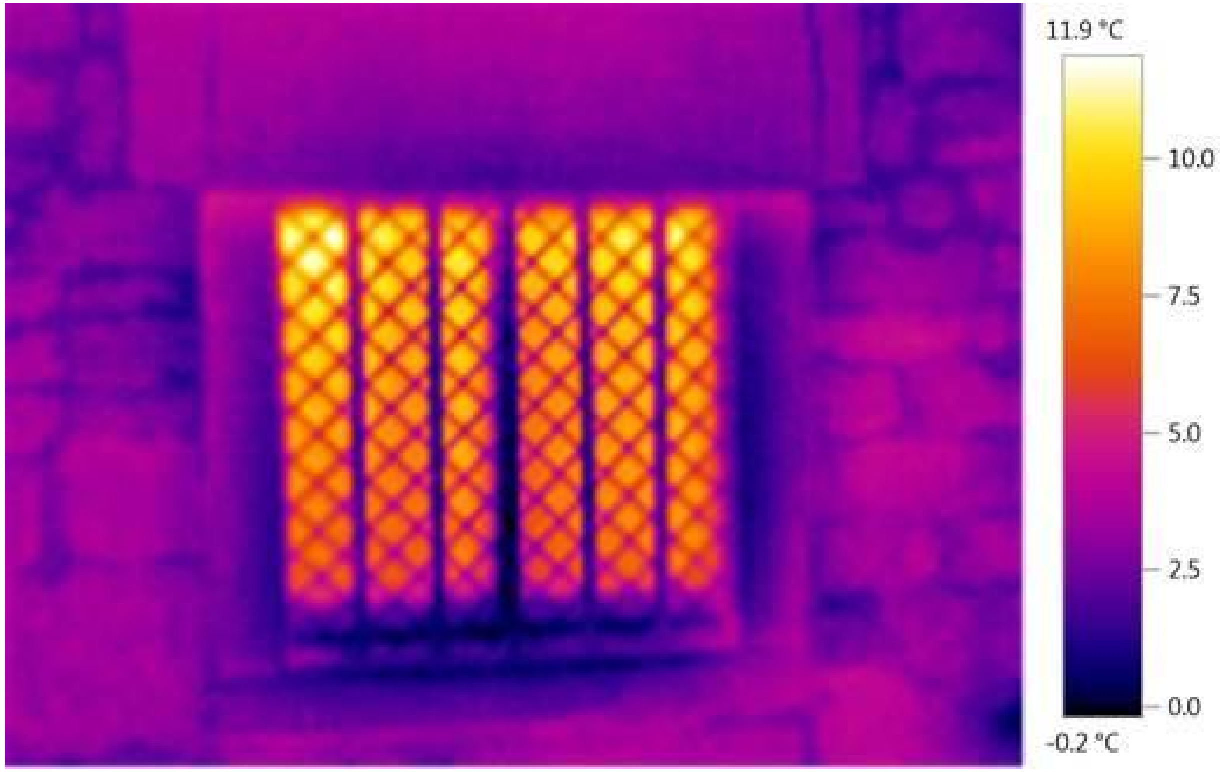
Windows - draughts



Observation: Badly sealed and insulated windows are common in homes, particularly wooden windows. Draughts are very common around wooden windows either where sash windows don't fit well or where warped. Double glazing often shows 'cold' spots around the edge of the glazing (called spacers), this is often not a real effect and is a result of different emissivity/reflection of heat. Windows can be difficult because of mix of materials and reflection of glass causing false positives. Can be improved by focusing in on one part of window containing single material

Remediation:

- Draught stripping of windows
- Bolting if warped
- For UPVC windows refitting seals
- Secondary glazing
- better fitting curtains

	This is the window in a room with a boiler installed. Clearly it would benefit from secondary glazing – the annual benefit through installing secondary glazing might be perhaps £215 per year; More importantly the room contained an old boiler with uninsulated pipework, upgrading the boiler might saving 20% of the home's gas costs.

Windows - heat loss and savings

Observation: Badly sealed and insulated windows are common in homes, particularly wooden windows. Heat losses from windows can vary significantly:

Type	U value (heat loss)
Single glazed metal frame	6.0
Single glazed wooden frame	5.0
Wooden frame with slim double glazing	2.6
Single glazing + secondary glazing	2.5
Older double glazing	2.5
Single glazing with well fitting shutters	2.2
New double glazing	1.5
New triple glazing	0.8 to 1.2
Slimline vacuum glazing e.g. Fineo	0.8

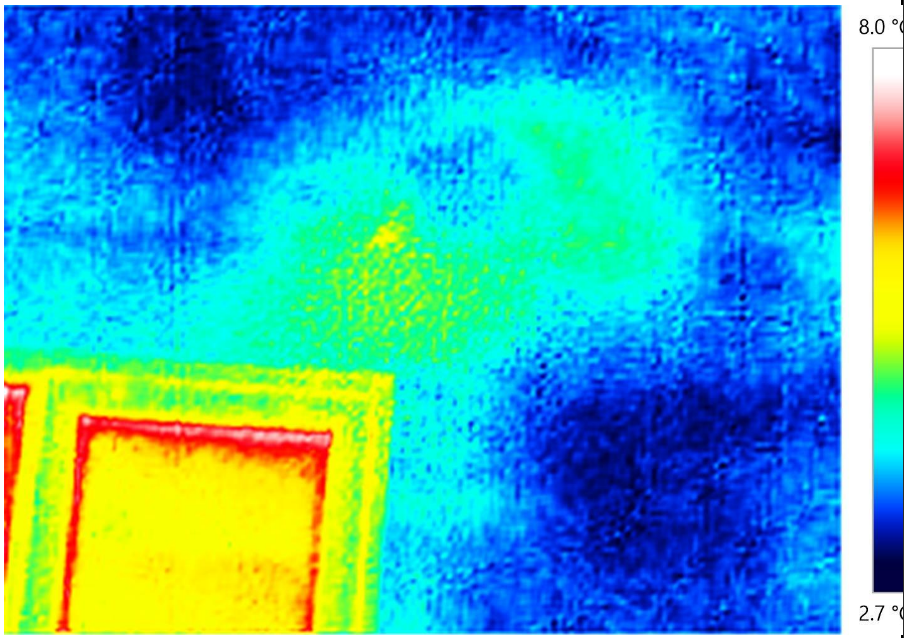
Installing secondary glazing or slimline double glazing to a wooden sash window can reduce heat losses by 50%, for windows which might contribute to 20% of a home's heat losses, so a 10% overall saving. Replacing windows can be expensive so might not always be the most cost effective investment. This report provides further background information for historic homes.

A simplistic rule of thumb is to multiply the area of a window by the change in U value by £4 to determine the annual savings. So for example if you were upgrading 4 x 1.5 m2 single glazed windows (U = 5.0) with secondary glazing (U = 2.5) you would save approximately 4 x 1.5m2 x (5.0 - 2.5) * £4 = £60 per year but the upgrade might cost you £600, so would take 10 years to pay back. Secondary glazing might also reduce draughts.

Costs: DIY secondary glazing £200/window, Professionally refurbished and draught stripped sashes £1000/window, new sash £1400, vacuum glazed sash £2000.

Thermal curtains can further reduce heat loss by 10% to 20% depending on how well fitting they are. However curtains can make heat loss worse if they redirect heat from radiators below windows onto across the window.

Walls - missing cavity wall insulation



Observation: Walls are where most heat is lost in most homes as walls are generally the largest external surface area. Most people assume thermal imaging cameras should be good at detecting insulation problems in walls but in general cameras can’t demonstrate problems with walls. Missing insulation in cavity walls generally doesn’t show up on thermal imaging cameras because heat losses within the cavity generally spread throughout the cavity through air convection and so areas of missing insulation can’t be identified. If you think you have missing cavity wall insulation you might need to wait for a very cold night and adjust the temperature range on your camera so rather than auto-ranging between the lowest and highest temperatures, just auto ranges between the highest and lowest temperatures of a wall - lookup the camera instructions then return the configuration to auto-range afterwards.

Remediation: Even if you are unable to see specific problems with walls using the camera you should still consider:

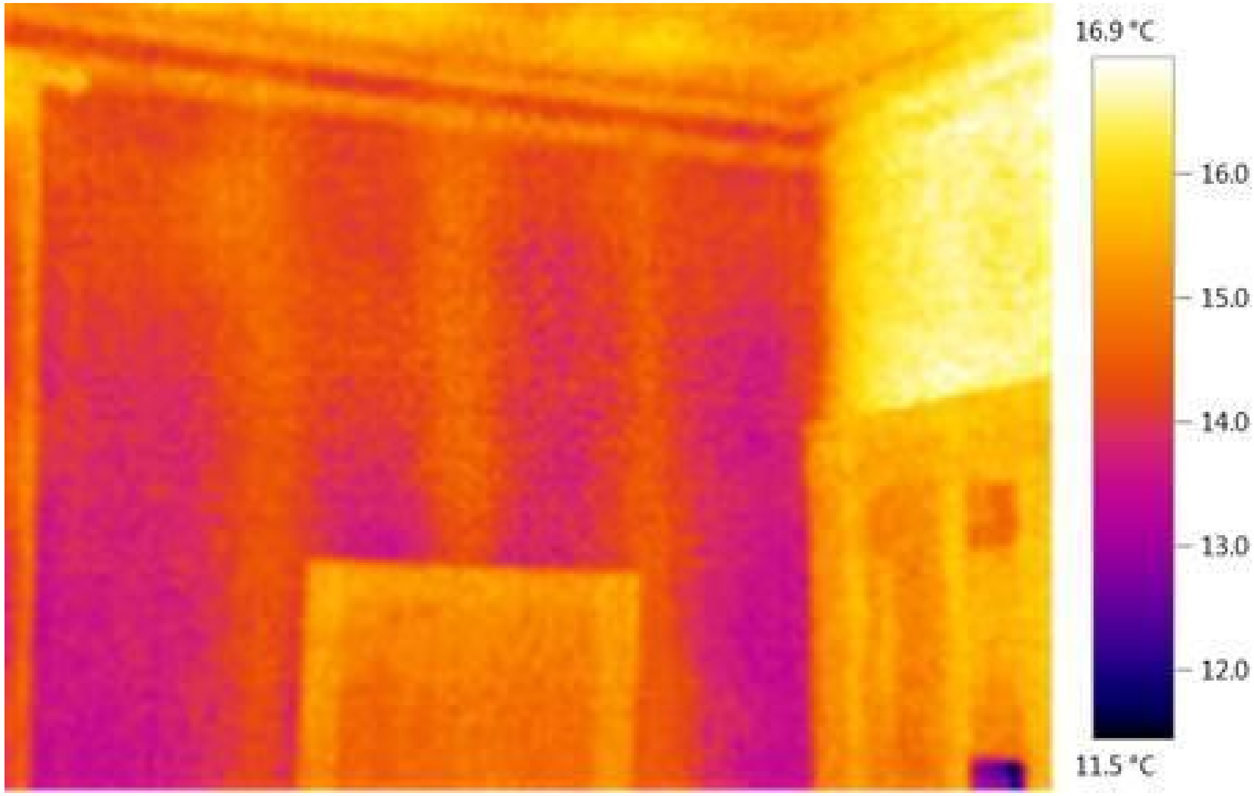
- installing cavity wall insulation if it hasn’t already been installed - recommended installers can tell you whether your home is already insulated
- Asking an installer to insert a video camera to determine if there is a problem with your existing cavity wall insulation; get it removed £2,500 and reinstalled £1,000. We would always recommend polystyrene bead over mineral wool
- installing external or internal insulation can be cost effective and very significantly reduce a home’s heat losses
- installing radiator reflector foil behind radiators on outside walls particularly of solid walled homes can be very cost effective, in addition to curtains above radiators direct heat from the radiators only the windows

Energy savings: if fixed it could your heat losses by up to 20%

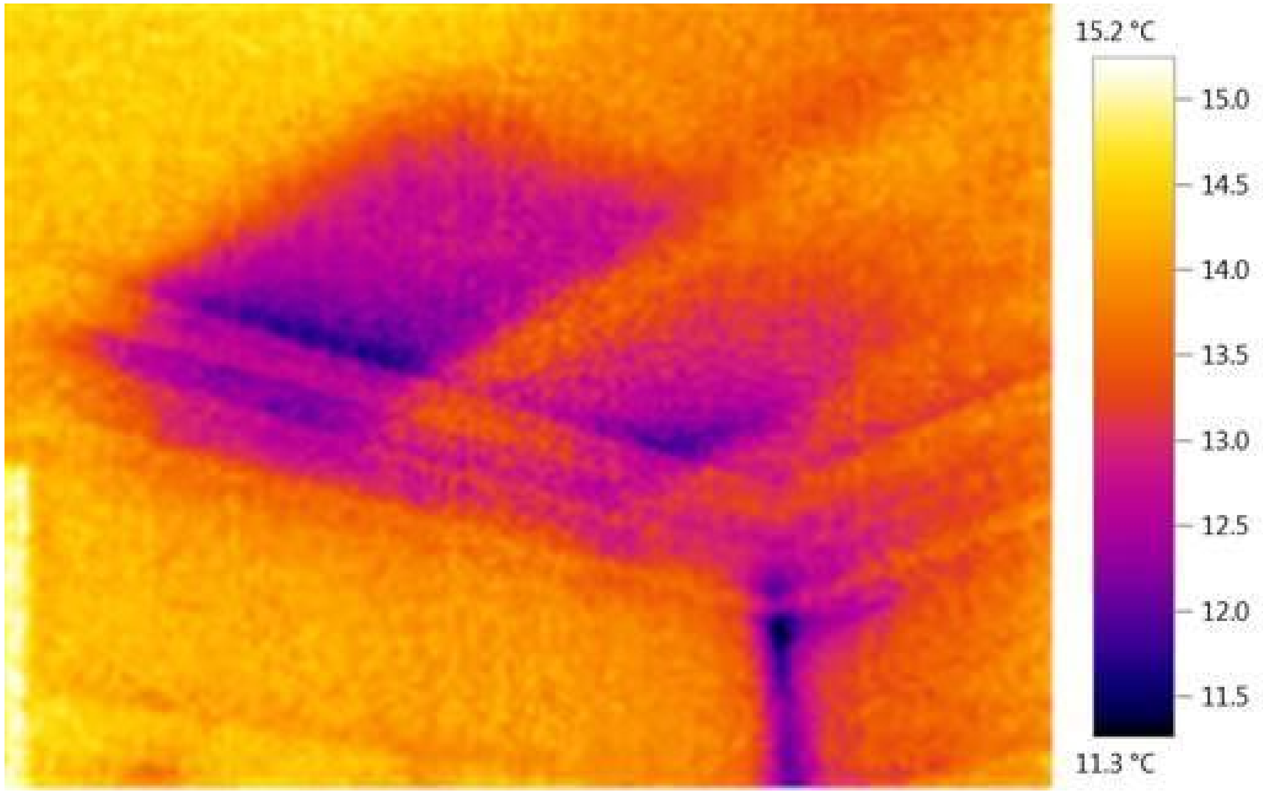
Internal and external wall insulation typically needs professional advice because of risks of interstitial condensation and structural damage.

Transition Bath community | food | energy | future   SHARE Repair   GO GREEN WIDCOMBE

Walls - dry lining

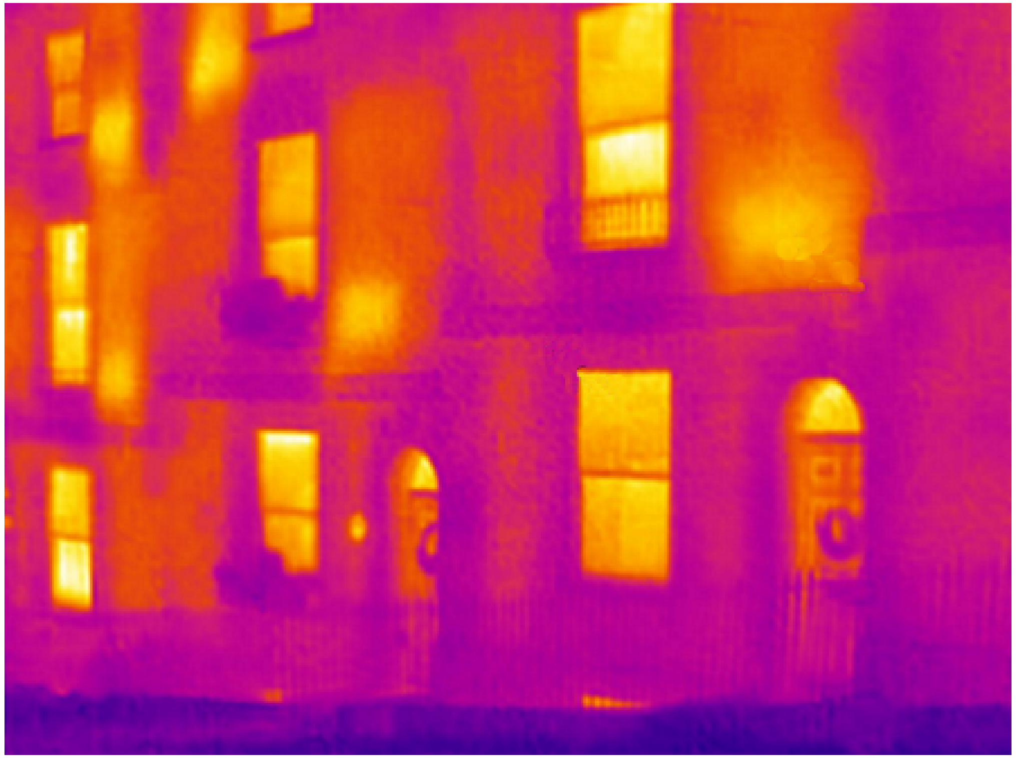
	**Observation:** Interestingly there is probably a hollow space behind this wall something the owner was unaware of. The construction is probably plaster on lathe battened to the wall. Heritage Scotland have been experimenting with injecting insulation into such a space to compare its performance with the alternative of solid wall insulation.

Walls - lack of insulation in ceiling voids



Observation: This house has solid wall internal insulation, which extends down the sides of the party walls but not up into the ceiling void. Cold from the uninsulated solid wall in the ceiling void is extending across the ceiling. There is a potential risk of interstitial condensation in this area.

Walls - Radiators on outside walls



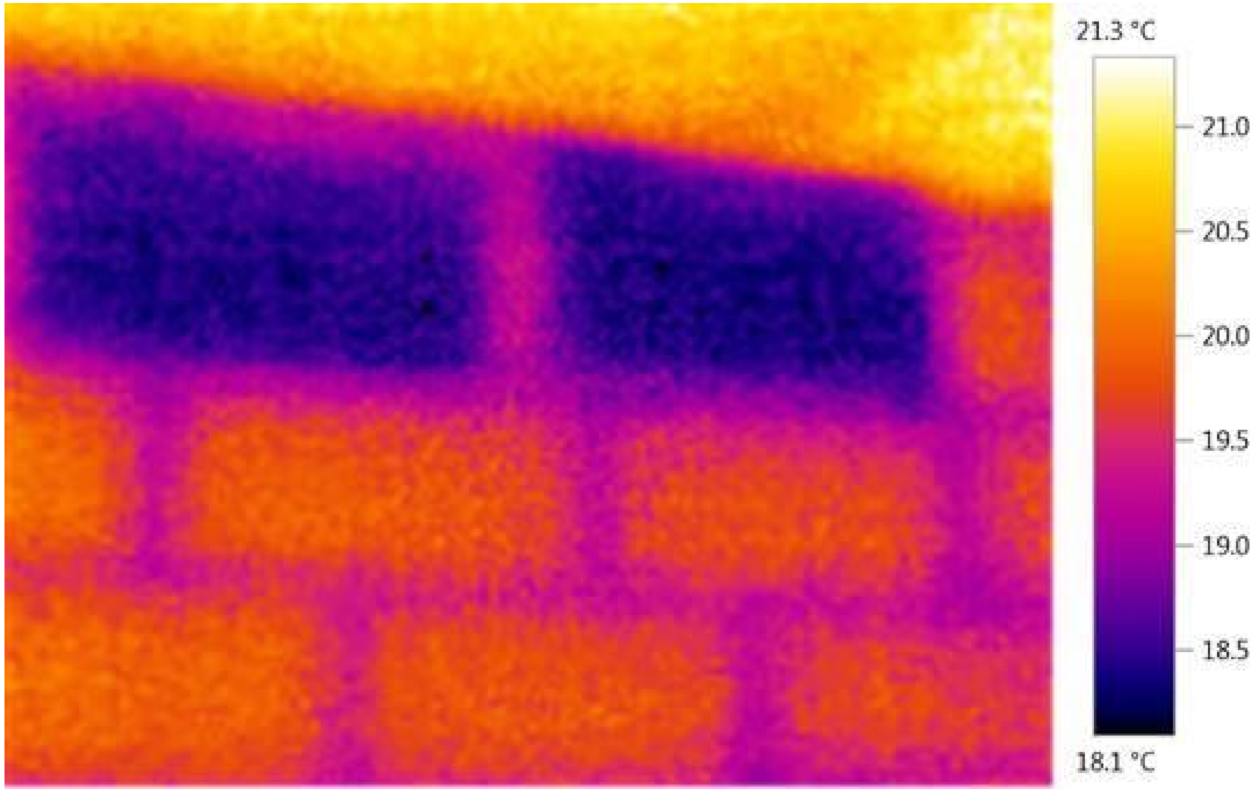
Observation: This is a very interesting result. This is looking from the outside of a Georgian property. To the bottom right of the window you can see heat from a radiator radiating out through the wall. Installing a reflective insulative strip behind the radiator would probably provide the house with significant benefit – it may be an issue which is common to many solid walled houses?

Remediation: Even if you are unable to see specific problems with walls using the camera you should still consider:

- installing cavity wall insulation if it hasn't already been installed - recommended installers can tell you whether your home is already insulated
- installing external or internal insulation can be cost effective and very significantly reduce a home's heat losses
- installing radiator reflector foil behind radiators on outside walls particularly of solid walled homes can be very cost effective, in addition to curtains above radiators direct heat from the radiators only the windows

Energy Savings: typical cost £5 per radiator reflector with a £5 annual saving

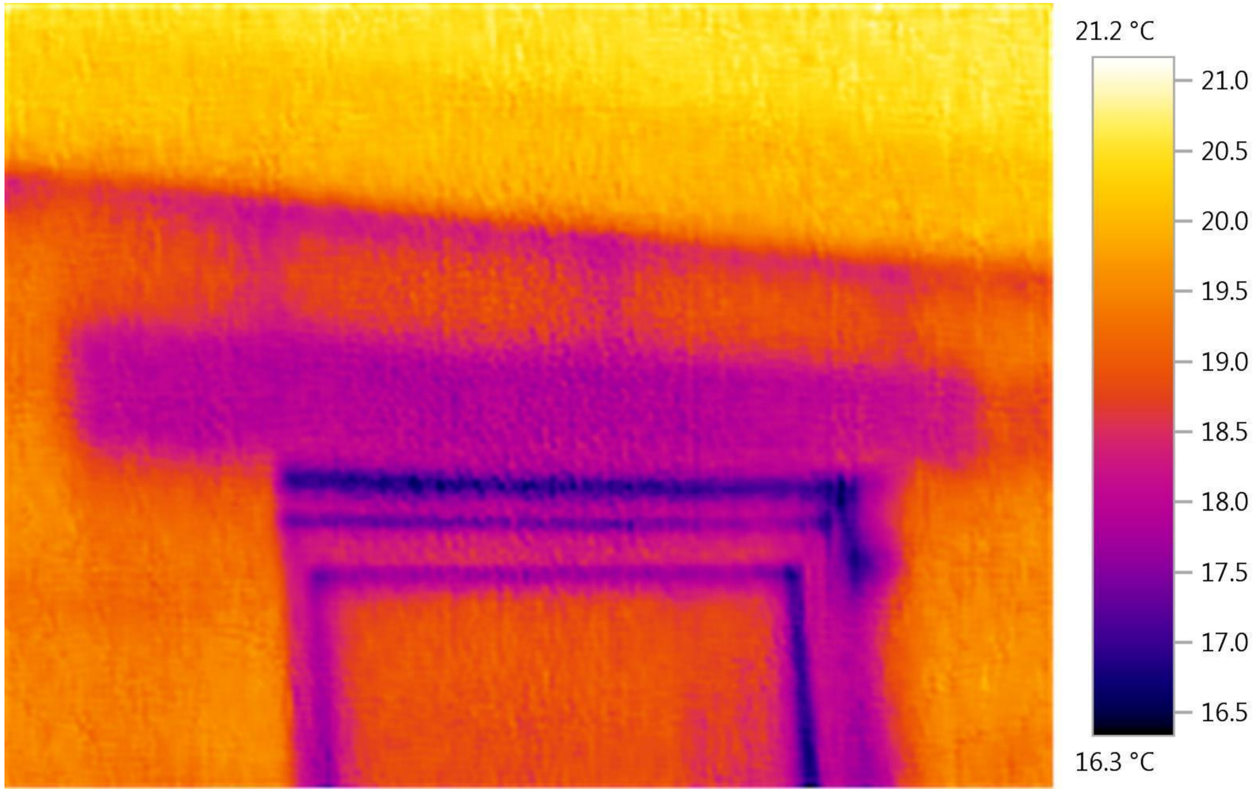
Walls - seeing mortar and high conductivity blocks through plaster



Observation: This is more of an interesting result rather than something which needs addressing from an energy efficiency perspective. In the right circumstances it is possible for the thermal imager to 'see' through plasterwork. In this example you can see 2 dense blocks in an internal wall which have much higher thermal conductivity than the Thermalite blocks below. You can also see the mortar which is more conductive than the block.

Remediation: there is little you can do apart from perhaps consider internal wall insulation. It would not be worth removing the blocks and replacing them or replacing the mortar

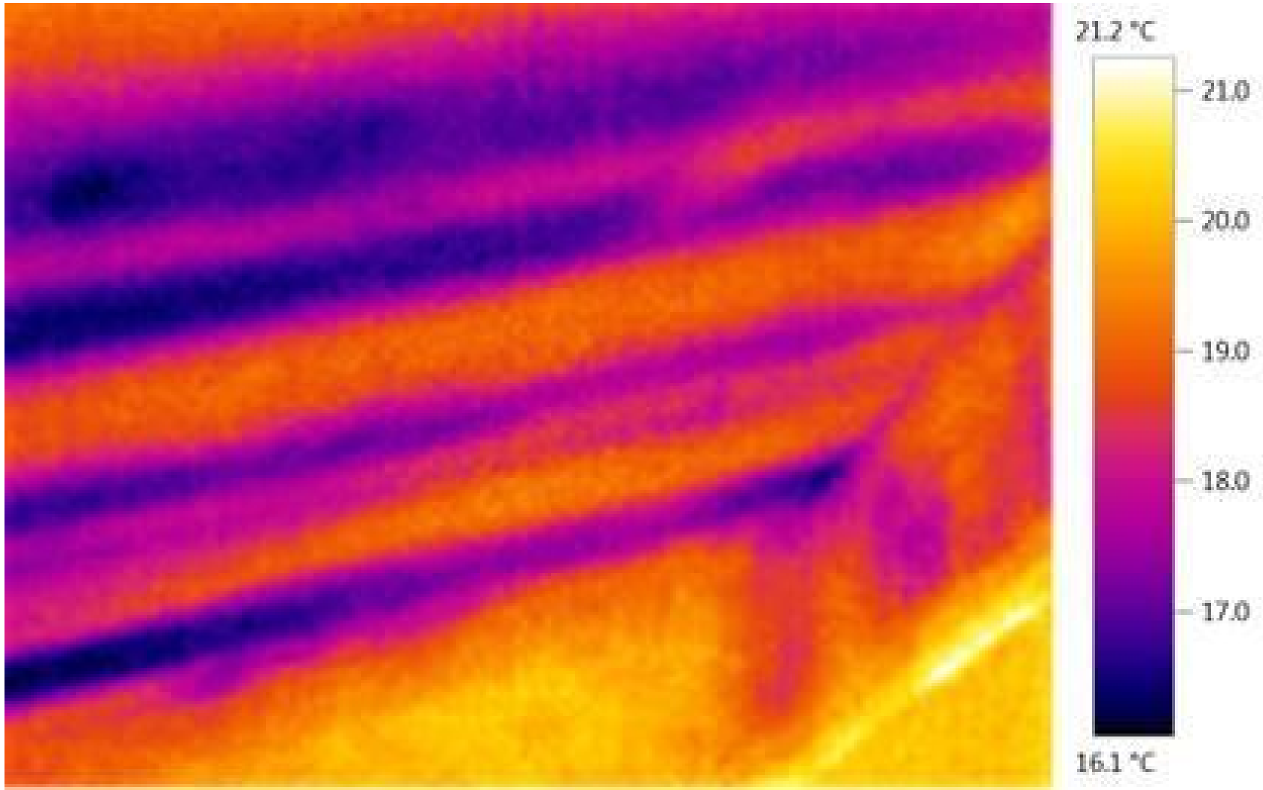
Walls -thermal bridging



Observation: Thermal bridging is where an element of a building's construction bridges from the inside to the outside bypassing insulation. This is an example of a thermal bridge through a window lintel in a 1980s house in Bath. You can also see the mortar joints between the block work above. There is very little you can do about this apart from replacing this lintel with an insulated (split) lintel which is probably not cost effective.

Thermal bridges are also common around window reveals. It is very common to see mould around windows, caused by thermal bridging making the window surround cold and causing them to attract condensation which ultimately causes mould.Insulating window reveals is only beneficial if done at the same time as replacing glazing.

Lofts - Missing insulation

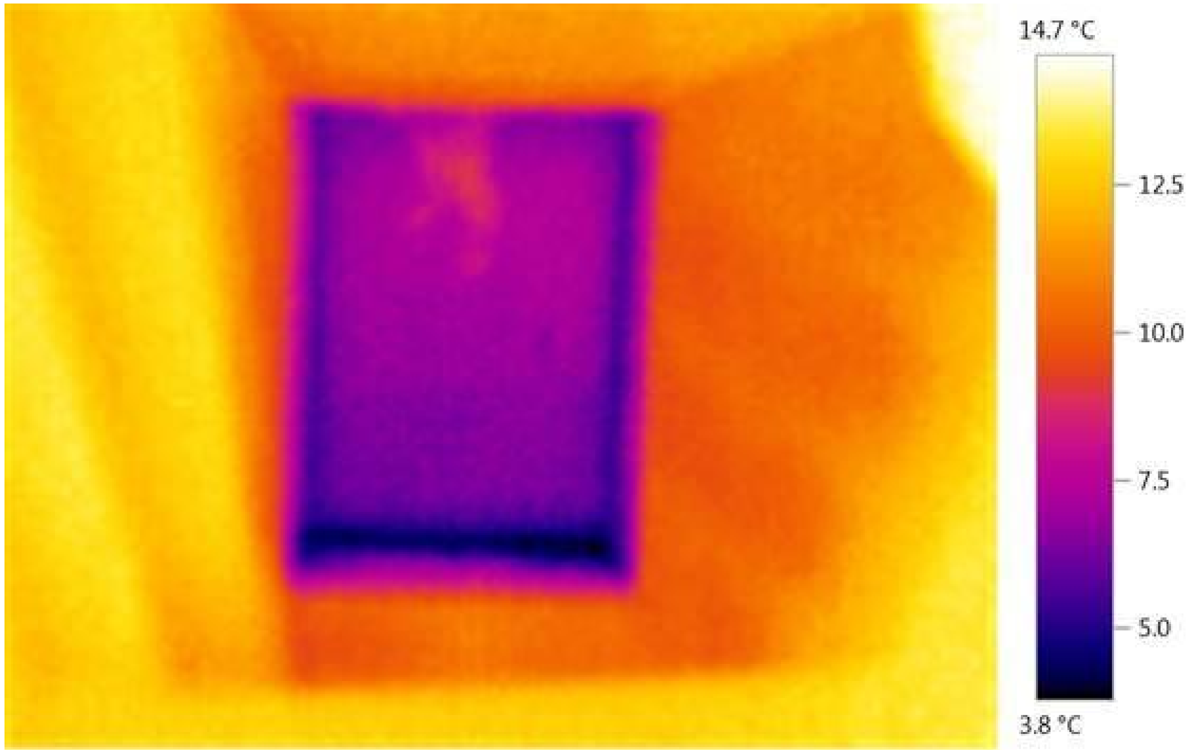


Observation: The ceiling area above this bathroom needs insulating. Its common to observe gaps in insulation of ceilings, and easily fixed by either filling those gaps or adding extra insulation. Observing gaps in ceiling insulation are best observed using the thermal imaging camera by lying on bedroom floors.

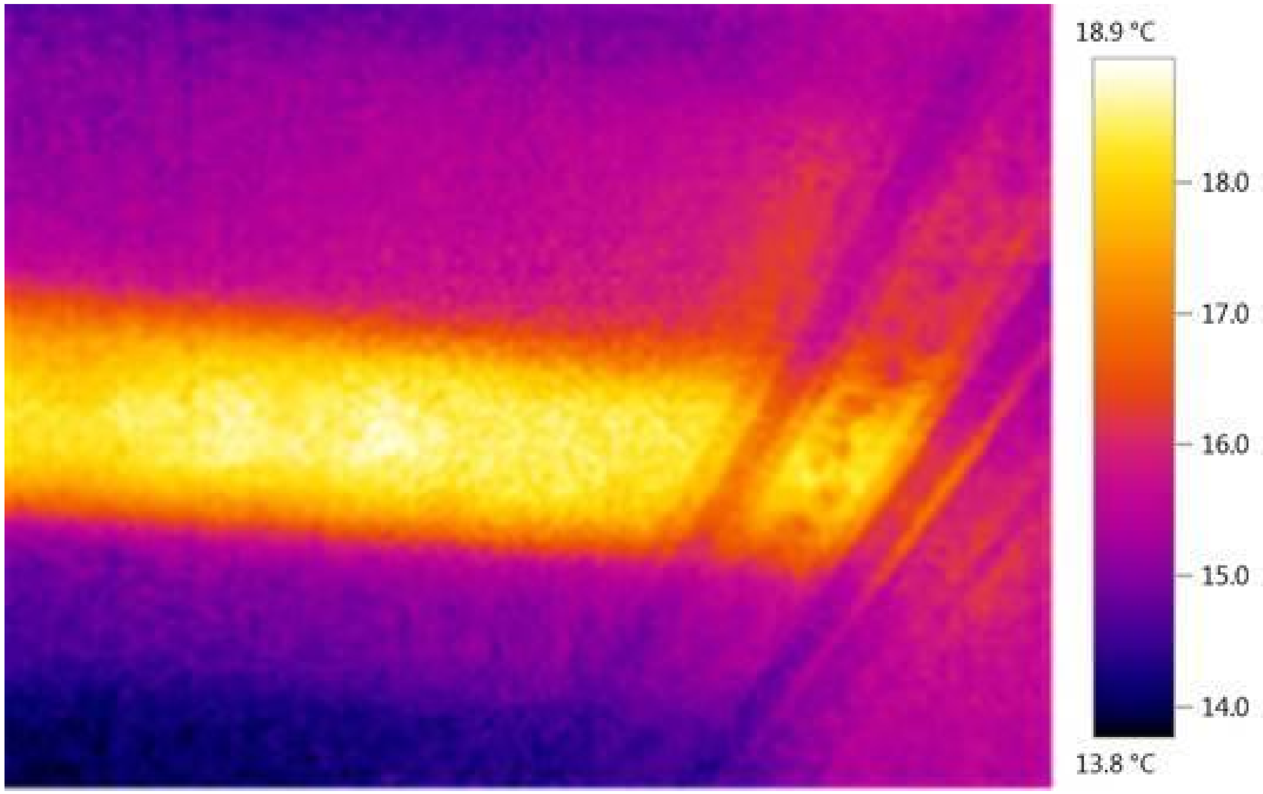
Energy Savings:

Change	Cost	Saving/year	Payback/ years
100mm => 250mm	£450	£25	18
100mm => 400mm	£650	£45	15

Loft Hatch

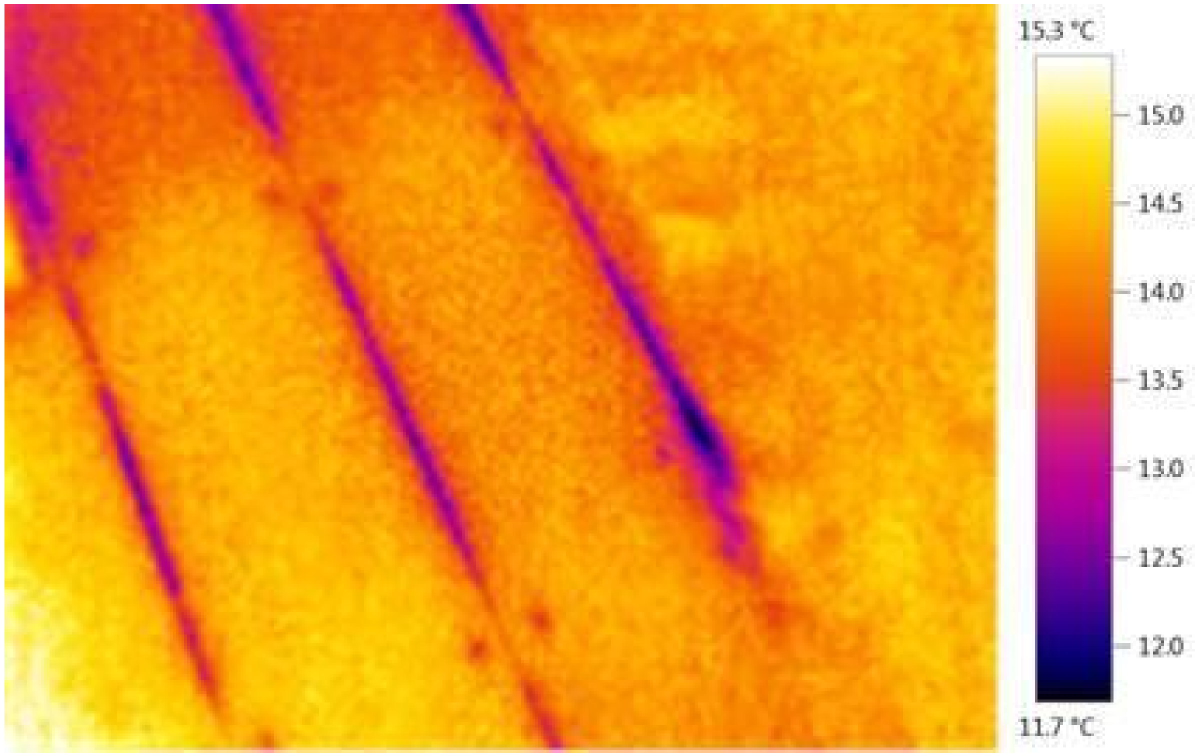
	**Observation**: This loft hatch could do with better insulation and draught stripping. **Remediation:** this is a simple DIY fix - putting some insulation in a plastic bag on top of the hatch or glueing solid (e.g. Celotex) insulation to the hatch, installing draught strips to the side of the hatch or wooded strips to reduce gaps **Energy Saving:** about £20 per year (£200 over 10 years) for £20 cost investment

Ceilings - uninsulated pipework



Observation: This image is one which was seen at perhaps 50% of the homes; hidden uninsulated central heating pipework between ceiling joists radiating heat into the ceiling void . Although not a significant loss as it’s typically within the thermal envelope of the house; if floorboards are being lifted then its worth insulating with pipe insulation

Floorboards - draughts and lack of insulation

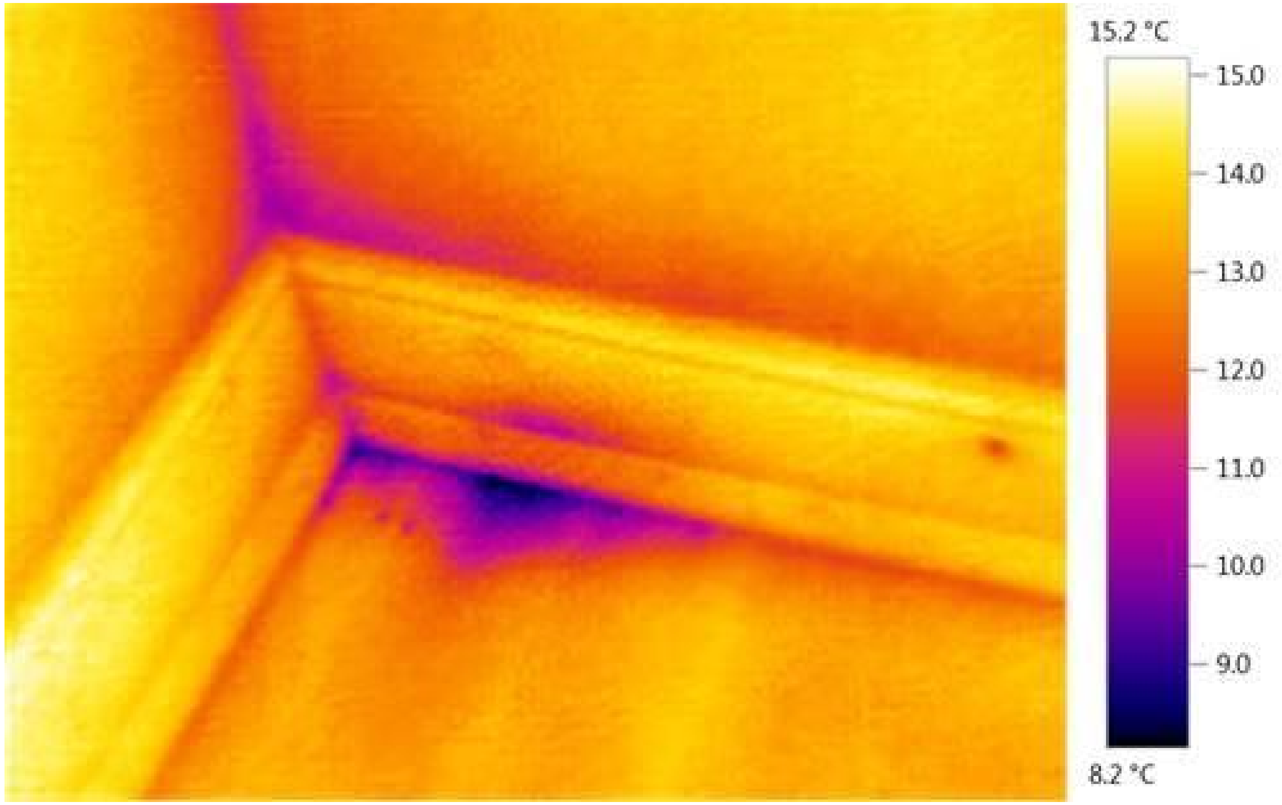


Observation: The floorboards in this house are letting cold air seep up from below and are uninsulated.

Remediations:

- install a carpet!
- insulate (typical costs £50 to £100/m2) including robot sprayers
- draught-strip - neoprene/rubber draught proofing strips are available; avoid V shape strips as often don't work well with vacuums

Floorboards - draughts under skirting boards



Observation: draughts under skirting boards

Remediation: easily fixed by running (bathroom type) silicon sealant under the skirting board

List of measures and potential savings:

£ values based on average of pre energy crisis and …

Payback is the number of years running costs it will take to pay off the capital installation costs of the measure.

Measure	Installation Cost (net of subsidies)		Annual Saving	Reduction overall home CO2	Payback years	Annual kWh before	Annual kWh after
	From	To					
Heating Systems							
Air Source Heat Pump (inc subsidies)	£3,000	£7,000	-£58	88%	-42.9	17500	4667
Ground Source Heat Pump (inc subsidy)	£6,000	£12,000	£51	90%	136.0	17500	4118
Installing a high efficiency gas boiler	£2,000	£4,000	£53	7%	57.1	10500	9450
Improved heating controls	£100	£400	£53	7%	57.1	10500	9450
Insulation and draughtproofing	Generally insulation is the most cost effective and impactful way of reducing a homes energy consumption						
Cavity Wall Insulation	£0	£800	£233	26%	1.7	10500	5411
External Wall Insulation	£7,000	£12,000	£428	53%	22.2	10500	1941
Internal Wall Insulation	£5,000	£10,000	£300	37%	25.0	10500	3329
Loft insulation	£200	£600	£85	10%	4.7	10500	8807
Underfloor insulation	£300	£2,000	£32	4%	36.2	10500	9865
Draught proofing	£0	£200	£74	9%	1.4	10500	9030
Glazing							

Sash window refurbishment	£100	£4,000	£37	5%	55.8	10500	9765
Double Glazing	£5,000	£10,000	£122	15%	61.2	10500	8051
Triple Glazing	£7,000	£14,000	£131	16%	80.4	10500	7887
Slimline double glazing	£7,000	£12,000	£102	13%	93.1	10500	8459
Secondary glazing	£2,000	£5,000	£102	13%	34.3	10500	8459
Miscellaneous							
LED lighting replacement	£50	£300	£54	1%	3.2	300	30
Solar PV	£4,000	£8,000	£300	7%	20.0		
Solar Thermal	£2,000	£5,000	£70	9%	50.0	3500	2100
Home battery storage	£2,000	£7,000	£200	0%	22.5		
Replace gas cooker/hob with electric/induction	£500	£1,500	-£33	3%	-30.4	657	328.5

And if you have gas heating, which is also used for hot water stored in a cylinder and for cooking, the heating may only account for 60% of your gas consumption, so reducing heat loss by `0% would only reduce your gas consumption by 6%.

How to calculate the impact of potential energy saving measures

It is possible to roughly calculate the benefit of an energy saving measure for yourself but it involves some maths. Heat loss of a fabric element e.g. a wall is measured in terms of its 'U value', this is the heat loss (watts) per degree of temperature difference per square meter (W/C/m^2). You can look up U values by searching online.

Example heat loss calculation for solid wall

An example might be an 'uninsulated cavity wall' which might have a U value of 1.5 W/C/m^2. If the external wall area (minus the area of windows, doors) of your home is 100 m^2 then the wall heat loss for the whole property would be:

1.5 W/C/m^2 * 100 m^2 = 150W/C

And if the temperature difference between the inside and outside of the building is 10C, then you would be losing:

10C * 150W/C = 1,500 W

1,500 watts of heat from your home. To compensate for this your boiler would need to generate 1,500 watts to offset this, which if the boiler was 15% inefficient would be about 1750 watts of gas.

If you then insulated the cavity, its heat loss or U value might reduce to 0.5 W/C/m^2 which would be a heat loss of

U value * area * temperature difference = 0.5 W/C/m^2 * 100 m^2 * 10 C = 500W

versus the 1,500W before, so a factor of 3, and a saving of 1,500W - 500W = 1,000W, which net of the inefficiency of the boiler would be about 1,200W. of gas power to offset the heat loss of your home.

Converting heat losses into cost savings

In the calculation above we have established that by insulating the cavity walls in our example home that with 10C of temperature difference between the inside and outside of the building that we would reduce the gas consumed by 1,200W (or 120 W per degree C). This is a measure of power, the energy being used in an instance in time. We now need to convert this to annual energy use, and this depends on where you live in the UK, for example the impact will be greater in northern Scotland than in southern England. Degree days also vary a little from year to year.

How cold it is measured in 'degree days' which is the number of days multiplied by how many degrees the temperature is below the base temperature, typically 15.5C in a year. The best place to get this information and for further explanation is https://www.degreedays.net/ .

For Bath there are typically about 1,800 degree days each year (compared to 2,800 in Scotland).

So to calculate the saving in kWh (1,000W for an hour), and assuming 24 hours in a day, with a heat loss of 120 W/C (1200w / 10C) you annual heat loss saving would be

1200W * 1,800 DD * 24 hours / 1000 W/kW = 5,200 kWh/year.

If you gas tariff was 10p/kWh then this would be a 5,200 kWh/year * 10p/kWh = £520 saving.