Heating and insulating buildings

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with thanks to Professor D.J.C. MacKay

From last time

power needed to keep a building warm

$$= \frac{\text{average temperature difference} \times \text{leakiness of buiding}}{\text{efficiency of heating system}}$$

e.g. a house...

- 3 bedroom
- semi-detached
- built about 1940
- thermostat at 20 °C, average temperature difference is 9 °C
- house is fairly leaky (draughts, poor insulation)
- original heating system is old gas boiler, about 70% efficient

Ways to save energy on heating your home

1. Reduce the average temperature difference. This can be achieved by turning thermostats down (or, if you have friends in high places, by changing the weather).
2. Reduce the leakiness of the building. This can be done by improving the building's insulation – think triple glazing, draught-proofing, and fluffy blankets in the loft – or, more radically, by demolishing the building and replacing it with a better insulated building.
3. Increase the efficiency of the heating system. You might think that 90% sounds hard to beat, but actually we can do much better.

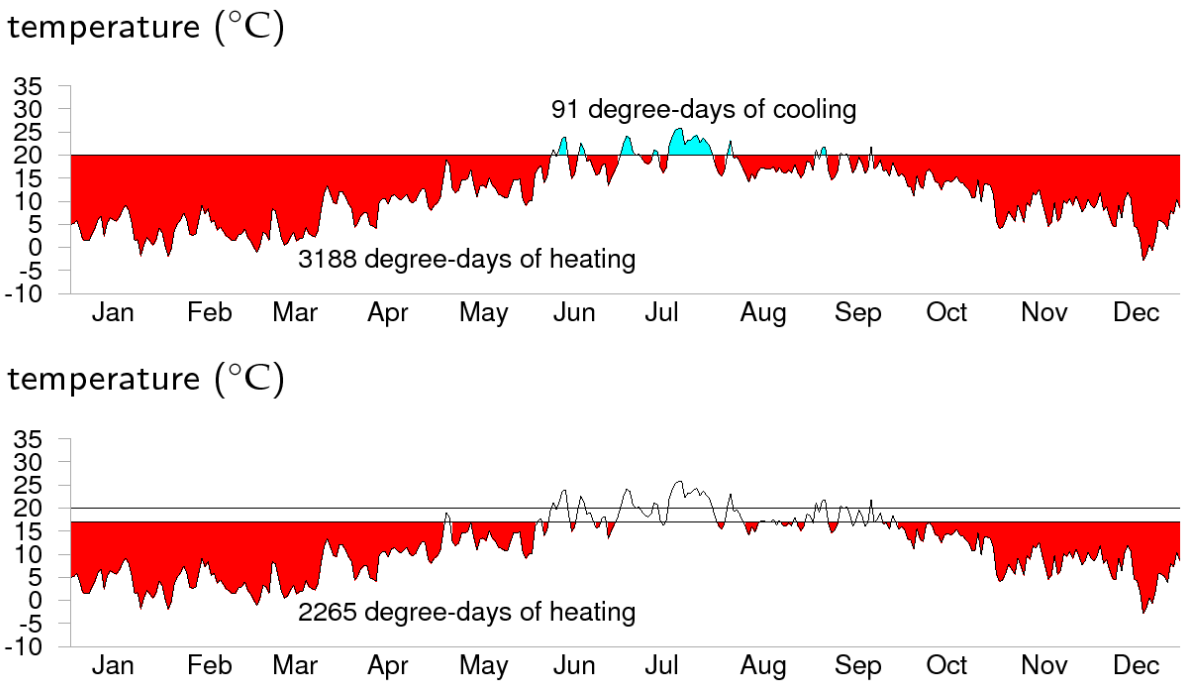
Reduce the average temperature difference

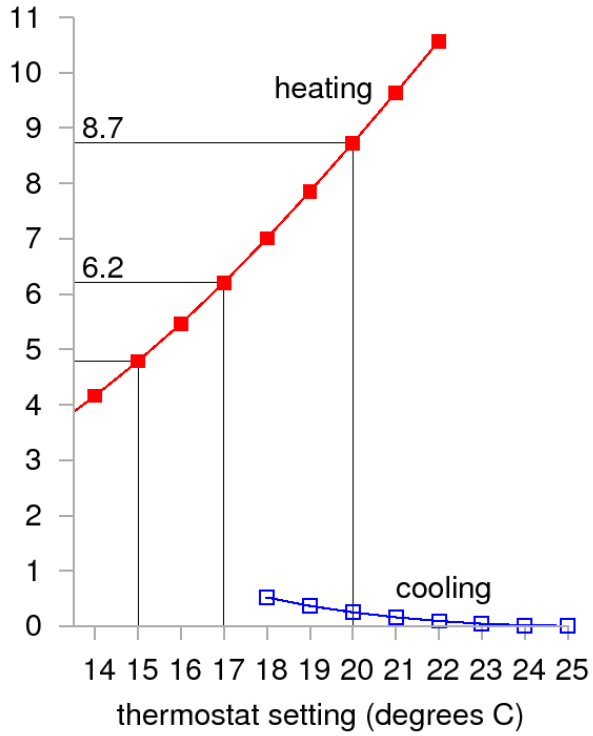
The thermostat (accompanied by woolly jumpers) is hard to beat, when it comes to value-for-money technology. You turn it down, and your building uses less energy. Magic!

In Britain, for every degree that you turn the thermostat down, the heat loss decreases by about 10%. Turning the thermostat down from 20 °C to 15 °C would nearly halve the heat loss.

Don't forget to turn the heating off when noone's home, too!

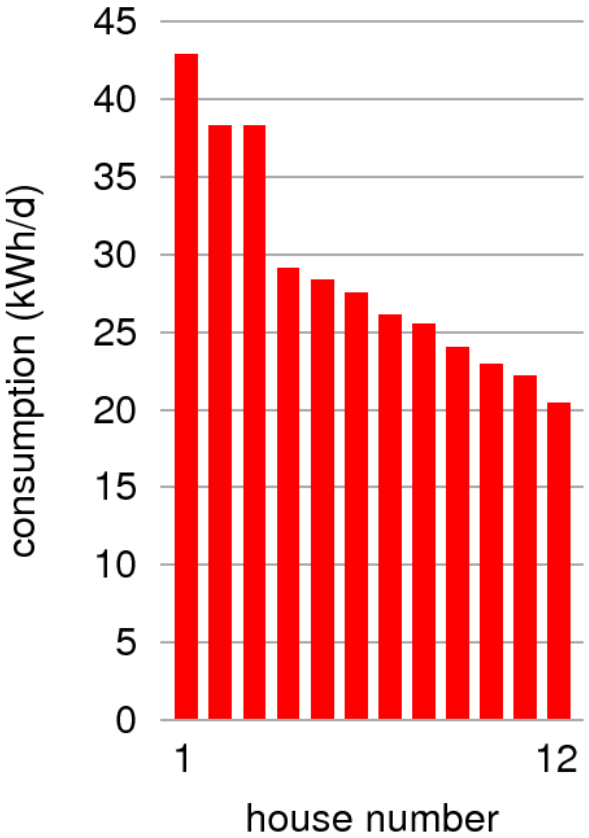
Cool technology: the thermostat





More on thermostats: What's a reasonable thermostat setting to aim for?

Nowadays many people seem to think that 17 °C is unbearably cold.
The average winter-time temperature in British houses in 1970 was 13 °C!
Try just leaving it at a really low value most of the time (say 13 or 15 °C), and turn it up temporarily whenever you feel cold. Thermostats don't need to be left up at 20 °C all the time.

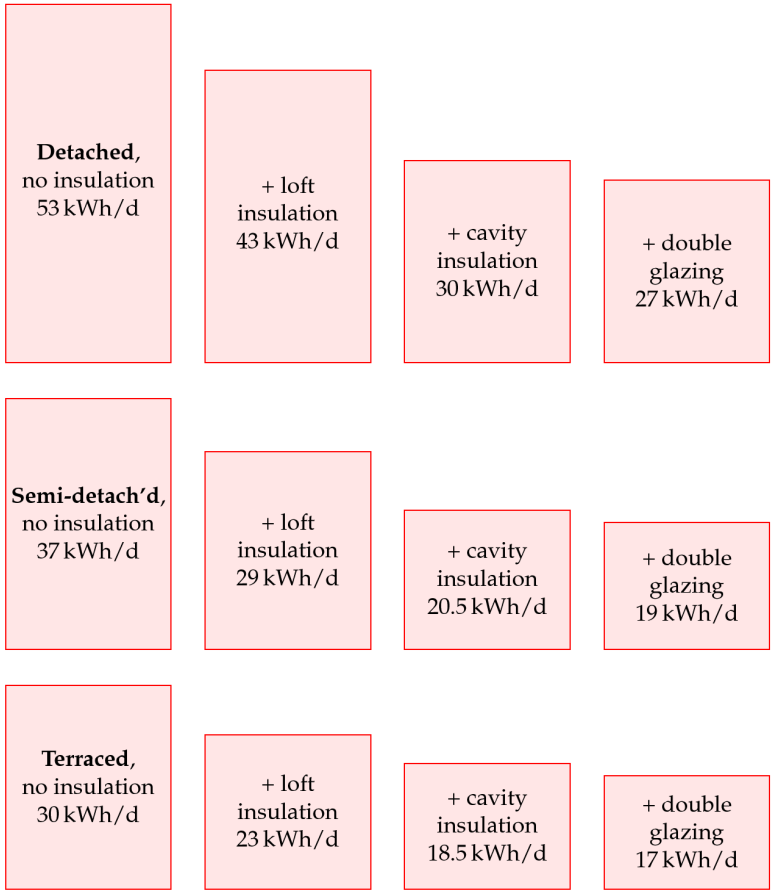


The war on leakiness

What can be done with leaky old houses, apart from calling in the bulldozers?
All the things we came up with in lessons:

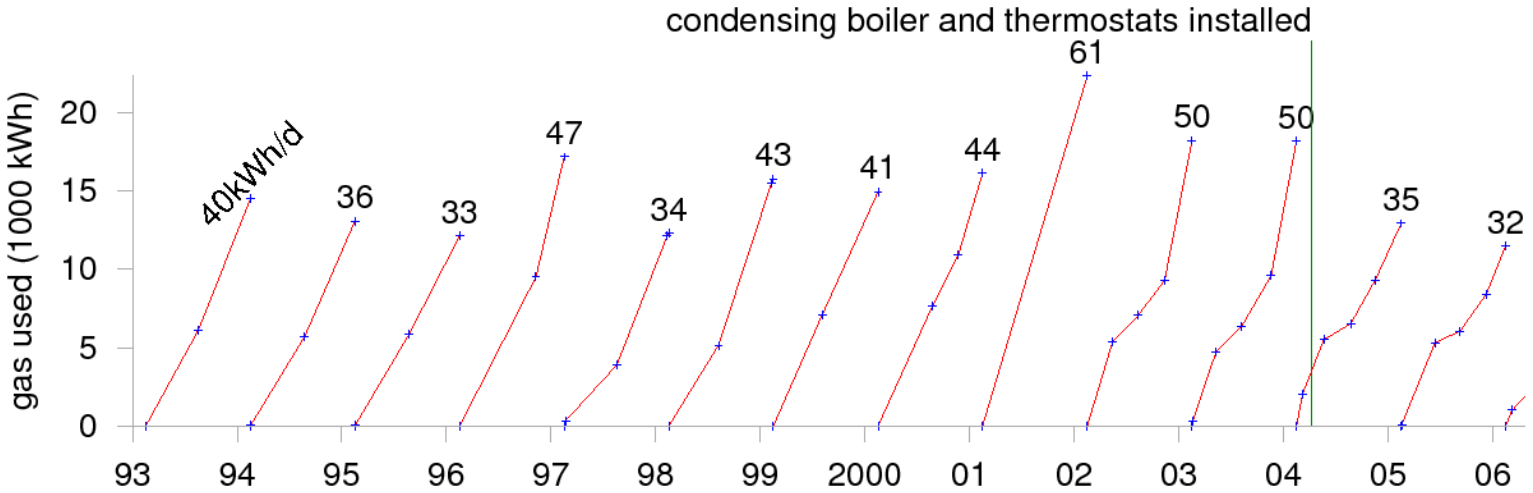
- Don't leave windows and doors open
- Loft insulation
- Double / triple glazing
- No cat flap!
- Use extractor fan less
- Cavity wall insulation

Patching up old houses



Power required to heat detached, semi-detached, and terraced houses as progressively more effort is put into patching them up. Adding loft insulation and cavity-wall insulation reduces heat loss in a typical old house by about 25%.

Back to our example house. . .



In 2004:

condensing boiler installed, replacing the old gas boiler (efficiency 70% to 90%)

house's hot-water tank removed (so hot water now made only on demand)

thermostats on all the bedroom radiators

new heating controller that allows different target temperatures to be set for different times of day

Estimating leakiness: U-values

The main sources of heat loss are **direct heat flow** through walls, floor, windows, and **ventilation** via draughts, losing hot air. The rate of conduction of heat through a wall, ceiling, floor, or window is the product of three things: the area of the wall, a measure of conductivity of the wall known in the trade as the 'U-value', and the temperature difference

$$\text{power loss} = \text{area} \times U \times \text{temperature difference}.$$

The U-value is usually measured in $\mathrm{W/m^2{}^\circ C}$. Bigger U-values mean bigger losses of power. The thicker a wall is, the smaller its U-value. Double-glazing is about as good as a solid brick wall.

Estimating total conductive leakiness

Conductive Leakiness	area / m^2	U-value / $W/m^2{}^\circ C$	leakiness $W/{}^\circ C$
Horizontal surfaces			
Pitched Roof	48	0.6	
Flat Roof	1.6	3	
Floor	50	0.8	
Vertical Surfaces			
Extension walls	24.1	0.6	
Main walls	50	1	
Thin wall (5 in)	2	3	
Single-glazed doors & windows	7.35	5	
Double-glazed doors & windows	17.8	2.9	
Total conductive leakiness			

Estimating total conductive leakiness

Conductive Leakiness	area / m^2	U-value / $W/m^2{}^\circ C$	leakiness $W/{}^\circ C$
Horizontal surfaces			
Pitched Roof	48	0.6	28.8
Flat Roof	1.6	3	4.8
Floor	50	0.8	40
Vertical Surfaces			
Extension walls	24.1	0.6	14.5
Main walls	50	1	50
Thin wall (5 in)	2	3	6
Single-glazed doors & windows	7.35	5	36.7
Double-glazed doors & windows	17.8	2.9	51.6
Total conductive leakiness			232.4

The story continues. . .

In 2007

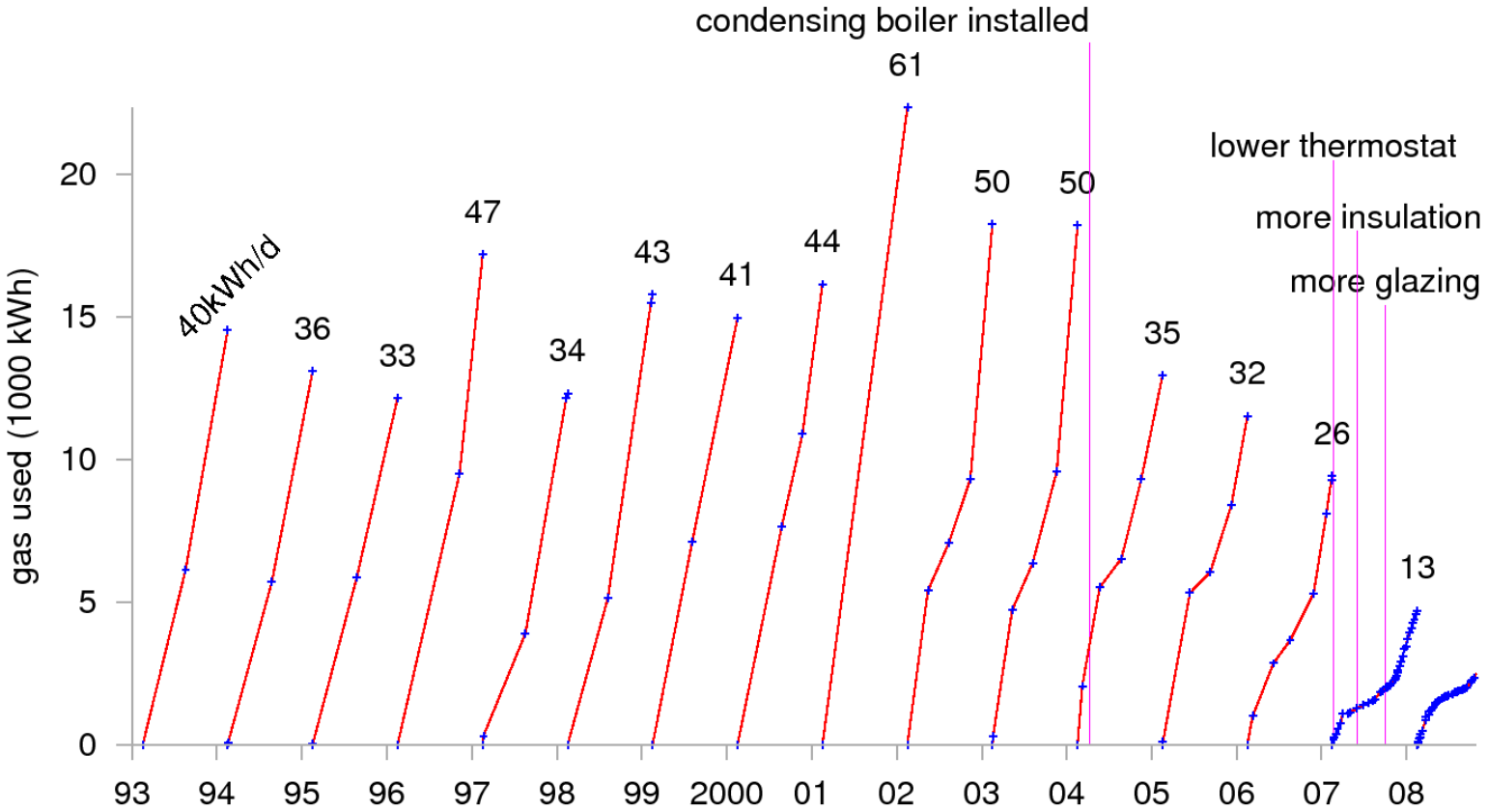
- started paying more careful attention to energy meters
- cavity-wall insulation installed
- improved loft insulation
- single-glazed back door replaced by a double-glazed door,
- extra double-glazed door added to front porch
- more attention to thermostat settings

New leakiness

Conductive Leakiness	area / m^2	U-value / $W/m^2{}^\circ C$	leakiness $W/{}^\circ C$
Horizontal surfaces			
Pitched Roof	48	0.3	
Flat Roof	1.6	3	4.8
Floor	50	0.8	40
Vertical Surfaces			
Extension walls	24.1	0.6	14.5
Main walls	50	0.6	
Thin wall (5 in)	2	3	6
Single-glazed doors & windows	7.35	1.6	
Double-glazed doors & windows	17.8	2.9	51.6
Total conductive leakiness			

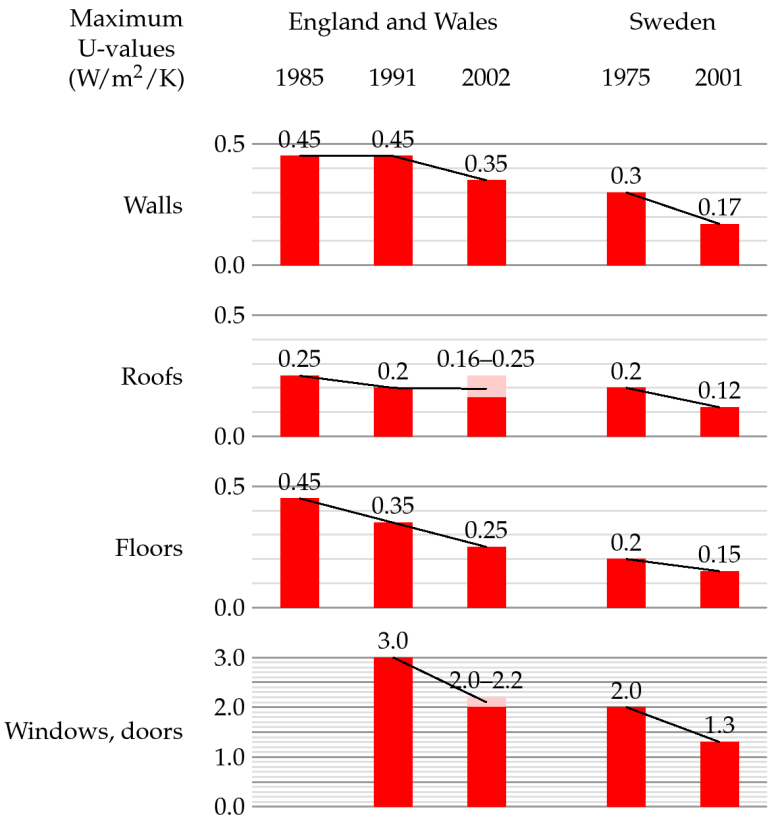
Result?

This attentiveness has led to a further halving in gas consumption.



BUT The leakiness of this 1940s build house is still much leakier than any modern house. It's frustratingly difficult to reduce the leakiness of an already-built house!

Better buildings



If you get the chance to build a new building then there are lots of ways to ensure its heating consumption is much smaller than that of an old building. Modern houses are built to much better insulation standards than those of the 1940s. But the building standards in Britain could be still better (see left).

Better buildings: key ideas

The three key ideas for the best results are:

1. have really thick insulation in floors, walls, and roofs
2. ensure the building is completely sealed and use active ventilation to introduce fresh air and remove stale and humid air, with heat exchangers passively recovering much of the heat from the removed air
3. design the building to exploit sunshine as much as possible