Does Passivhaus Pay?

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History

In March 1983, I stayed in a 'superinsulated retrofit' in Boston, USA. The three-storey row house with basement was of timber-frame construction [i]. In 1985, I visited a similarly ambitious retrofit in Toronto, Canada, featuring a solid brick-walled 'heritage building'.

In 1994, I visited a 'chainsaw' retrofit' in central Canada. It gained its nickname because the rafter overhangs were removed using one of these, as a prelude to insulating and draughtproofing the house thoroughly from the outside. The work went ahead in 1982.

These retrofits were the sequel to the new superinsulated buildings which began to appear in North America after 1975 [ii]. Doubtless, today, we'd call the new buildings 'Passivhaus' and the retrofits 'Enerphit'.

But except for significant advances in energy-efficient windows [iii], the techniques being applied are almost unchanged from the 1970s. The change is the sheer increase in numbers and their spread outside Scandinavia and North America [iv].

This opinion piece is on new buildings, but retrofits present a similar dilemma. What is 'enough' insulation, given the expense of adding it to a building, compared to how much energy costs now and may cost in the future? How much is 'too much'?

Optimum Insulation?

I've always been a fan of well-insulated and draughtproof buildings. They're more comfortable, they save on bills and they reduce CO_2 emissions.

By these simple standards, the UK record is uniquely atrocious. It still allows houses to be built whose walls just about meet Denmark's *1977* Building Regulations [v].

But as we add more insulation, practical limits do emerge. The optimum insulation level for a new natural gas-heated building; i.e., the amount which minimises mortgage plus energy costs, can be calculated. It lies somewhere between 'Part L' and the Passivhaus Standard. Some continental countries require this in their Building Regulations [vi].

Diminishing Returns

Passivhaus Standard projects have been known to use as much as 350-450 mm of wall insulation. But here is a hypothetical case, based loosely on examples I have seen [vii].

A 120 m^2 one-off detached house in a Midlands town aims to meet the Passivhaus Standard. It is calculated that the 'last' 25 mm of wall external insulation; i.e., increasing the thickness from 225 to 250 mm, adds £320 to the house's construction cost and saves the owners 144 kilowatt-hours (kWh) per year of natural gas.

The calculations are made at an internal temperature of 20°C. Slightly higher temperatures are likely to be maintained in practice. This would slightly shift the calculation towards favouring more insulation. But it would not change the basic conclusions.

144 kWh of gas is worth £5.76. So this improvement in thermal standards, from 225 to 250 mm, gives a return on investment (ROI) of 5.76 x 100/320 = 1.8 % per year. A rise from 250 to 300 mm of thermal insulation would save £8.64 per year worth of gas and have a ROI of 8.64 x 100/640 = 1.35 percent per year [viii].

Put another way, an incremental shift from 225 to 250 mm wall insulation is equivalent to paying around 8.4 pence to save a kWh of natural gas [ix]. A shift from 250 to 300 mm would be equivalent to paying 11.3 pence per kWh saved. 1 kWh of gas supplied to the domestic sector costs 4 p [x] [xi].

Large-scale solar heat in Denmark; i.e., delivered via heat networks, may be quite a good deal compared to this 'ultra-high' insulation [xii]. It could also compare well to other approaches to future urban heat supplies; e.g., the government's plan for an electric heat pump in every building [xiii] [xiv]. To say the least, the subject seems to deserve more scrutiny and debate than it has received.

Applying the Passivhaus Standard seems like the highest priority in rural areas where other heat supply options are not feasible [xv]. For many years, the heating fuels available here have cost considerably more than natural gas, helping to justify higher fabric thermal standards.

Predicting the Future?

It was suggested in 1977 that ultra-low heat loss buildings would pay for themselves in a future of 'much higher energy prices' [xvi]. Expect it to arrive by the early 21st century, most 'experts' thought.

'Fast forward' to 2015, though, and one may note that fuel to heat buildings, and thermal insulation to reduce their heat loss, cost the same in real terms as they did 38 years ago [xvii]. What was that comment about 'much higher energy prices'? Take care in making similar predictions [xviii].

Heat Planning

Denmark has done outstandingly well since the 1970s in cutting the fossil fuel usage and CO_2 emissions associated with keeping people warm. 'Local heat planning', combining well-insulated buildings *and* low-CO_2 heat networks, has delivered lower CO_2 emissions for less cost than uncoordinated, 'liberalised' arrangements. One might think from the stony silence in other countries that they have money to burn.

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Policy Priorities

It is the implementation of *affordable* energy investments that has caused UK energy consumption to fall slowly, placing several very expensive energy supply investments in question [xix]. Let's pursue this area more enthusiastically [xx].

More energy-efficient lights, appliances, office equipment, central heating pumps and fans cost less than building new power stations, including wind and solar ones. High-performance condensing boilers, improved controls, insulation of DHW tanks and pipes and connecting existing buildings to low-CO_2 waste heat from existing power stations cost less than making a thick urban building fabric even thicker.

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Notes

[i] They also offer lessons on how to insulate UK timber-frame buildings. These form a significant proportion of the building stock. But they remain mostly untouched by retrofit activity.

[ii] Starting with landmark projects like the 1976 Lo-Cal House, USA and Saskatchewan Conservation House, Canada.

[3] Such as warm edges, low-e glass, low-e plastic films like HM-88, heavy gas fillings and insulated frames. The 1970s 'superinsulated' buildings used three or four panes of glass in wood frames.

[iv] In North America, their application is mostly restricted to before the late 1980s and after the mid 2000s. Not all North Americans building these houses now know that the techniques were widely applied 30-40 years ago, forgotten as oil prices collapsed and rediscovered 20 years later.

[v] A brick/block cavity wall, fully-filled with 100 mm mineral fibre batts was in the Danish BR-77 and is sometimes seen in new houses in the UK in 2015.

[vi] In 'moderate' climates, such standards might entail using 160-200 mm insulation in a new masonry wall. The AECB Silver Standard, set at such a level, broadly pays for itself, using gas heating. The thicknesses cited refer to air-based insulants, such as EPS foam and mineral fibre batts.

'Moderate' climates, in this context, include most of England, Wales, the Low Countries, Germany and Switzerland. A 100 m^2 building with this level of heat loss and a gas condensing boiler would have a space heating cost of £150/year, assuming gas at 4 pence per kWh. This excludes any standing charges payable.

[vii] The example assumes that added external insulation of a 'normal' EPS foam, with λ=0.036 W/mK, costs £80 per m^3. This marginal cost comprises the material itself plus the additional structure to support it, e.g., deeper door and window sills and reveals; wider roofs; use of more insulation and cladding at the corners of buildings.

[viii] Another example, intended to apply to a cavity-walled house, is given in this blog: http://www.energyadvisoryassociates.co.uk/blog/page/3/. Also the fuel saving is often offset by the extra Council Tax liability, illustrating another government policy that needs revision.

[ix] These sums are done from the nation's viewpoint, using the real interest rates set out in the *Treasury Green Book*. The rate is normally a real 3.5 percent/year but is somewhat lower for assets lasting beyond 30 years. The insulation is assumed to be paid for over 60 years.

[x] If one switches from the 'Big Six', gas is available at a lower 2.2-2.6 pence per kWh. In exchange,

one is liable for a slightly higher standing charge. See; e.g., https://www.ukpower.co.uk/home_energy/tariffs-per-unit-kwh.

xi Independent, 'like for like' costings of buildings with moderately high to very high insulation were done decades ago; e.g., by Nørgård in his book *Buildings and Energy* 1977, analyses of the Salford low-energy houses in the early 1980s and two houses by Dumont in Saskatoon, Canada in the mid 1980s and mid 1990s.

Comparing costings of 'energy-efficient' buildings by very capable design teams to Buildings Regulations-compliant buildings by average design teams can lead to overoptimism. So can looking at 'energy-efficient' buildings which utilise a 'new' construction material and/or system and comparing to 'control' buildings that utilise 'standard' materials or systems.

xii Estimates of the cost of solar heat from a large installation, with 50,000-100,000 m^3 or more seasonal storage, appear to be 2.5-4 p per kWh.

xiii A heat pump in a building usually costs more than a gas boiler or a connection to a heat network. Before widely applying them, as the government plans, the national grid would need new substations and fatter cables. These would enable the higher peak demand to be accommodated.

xiv *Long-Term Experiences with Solar District Heating in Denmark*, Leo Holm, Marstal Fjernvarme (2012).

xv I accepted this argument when designing and building my own house: www.energyshowcase.org.uk. Also, rural houses are usually higher above sea level and more exposed to wind than urban houses. Both features are associated with a higher heat load.

xvi Nørgård, J S, *Buildings and Energy*, 1977. Nørgård is best-known for his landmark analysis of the scope for more energy-efficient electrical appliances but worked on other areas of energy efficiency too.

xvii Adjusted for inflation and comparing the relatively high oil price around 1973-74 and 1979-82 to its price in 2005-14.

xviii As Niels Bohr said, 'Predictions are difficult, especially about the future'. Many analysts now argue that energy price rises are limited to what consumers can afford. If oil prices 'spike', the economy does not 'motor on' as before. It may go into recession as consumers and businesses find themselves paying out more on fuel, leaving them less to spend on anything else.

If long-term energy supply costs are set to rise, versus oil, it is hard to see a way to avoid economic disruption except seeking out a vast range of energy efficiency investments that are lower in cost than fossil fuels. Sufficient investment might be able to counteract the inexorable rise in energy supply costs which is underway as renewables supplement fossil fuels.

xix http://www.ukace.org/2014/04/its-official-energy-consumption-in-the-uk-is-on-the-way-down/

xx One significant way to speed it up could be to 're-regulate' the UK's gas and electricity companies. They were regulated for the 12-14 years from 1988-90 to 2002; i.e., after privatisation but before so-called 'deregulation'. Suppliers of this type could be asked to invest in least-cost measures on consumers' behalf and sometimes on consumer's premises; they would be able to earn a return on it. See *LESS IS MORE: Energy Security After Oil,* AECB February 2012.

See also http://midwestenergynews.com/2013/10/08/how-denmark-turned-an-efficiency-obligation-into-opportunity/. But as Danish energy companies are in theory consumer-owned, it is not certain how easily this model could transfer to the UK. The UK's utilities do, however, have a parallel to the regulation of US 'investor-owned' utilities.