# Is net Zero the right target for buildings?

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## 1 Introduction

Zero energy buildings are a seductive concept. Peter Harper's 1976 essay the *Limits of Material Autonomy* explored the concept in detail concluding that: '*It is a seeming paradox that each extension of the scope of economic and material autonomy, if it is to remain honest and non-exploiting, requires commensurate measures of collective participation.*' [Harper 1976]. Whilst Harper and many other pioneers have long since abandoned the 1970s counter culture ideal of the autonomous house, it has been reinvented and is now promoted in its current guise as national policy.

**Figure 1. All-electric zero carbon Passivhaus vicarage.**

Whilst some still favour genuinely autarkic buildings, it is now more usual to replace the cost prohibitive batteries or fuel cells with a connection to the grid. Typically to qualify as 'zero' the exported energy must equal the imported energy over an average year. In the UK the preferred metric is carbon with all new homes required to be 'zero carbon' by 2016. The fast approaching deadline has inspired a UK Government consultation to re-define 'zero'. Even outside the UK there is considerable confusion over definitions around so-called 'zero energy', 'zero carbon' and 'zero emissions' buildings.

Some Passivhaus advocates see net zero as a logical step given the already low energy consumption of Passivhaus building. Others have argued that it may be cheaper to add PV to a sub Passivhaus building than to add extra insulation with diminishing returns in order to reach the heating energy target of 15kWh/(m$^2$.a) [Holladay 2011].

In this paper zero will be used loosely to include near zero and beyond zero energy and carbon buildings, ie any building that aims to offset a significant amount of its life cycle energy use or emissions, on-site. Rather than adding to the debate about zero carbon definitions and pathways, this paper suggests that the idea of net zero applied at the building boundary, is a flawed concept that is best abandoned.

Scepticism of zero carbon buildings does not imply dismissal of the need to achieve a net zero carbon Britain, Europe and World. This is an almost unimaginably daunting task that is currently being hindered by expensive deviations down blind alleys.

# 2 Example, A Zero Carbon School

The first ‘zero carbon’, certified, Passivhaus school in the UK was completed in October 2011. It is designed around a 167.79kW PV array shoehorned onto a South facing mono-pitch roof. As with other projects, the PV has clearly influenced the building design leading to two storeys to the North and one to the South. The predicted annual output of the array is 168 MWh, within 1% of the calculated demand of 166 MWH [Solarsense 2011]. All space heating, hot water and cooking is by direct electric resistance heating. As with other projects, gas heating was rejected because it is a fossil fuel.

This raises a number of questions, for example, do we really believe that generating capacity and predicted demand can be matched within 1%? Where enthusiastic occupants are minded to watch their meters, such a limit could be seen as an effective but costly feedback loop to inspire energy efficient behaviour. Conversely another occupant might consider the onsite-generated electricity to be free to use, and increase energy use accordingly. As one PV user said ‘In the winter I now put my halogen heaters on instead of the central heating as I know they are probably cheaper than the gas’ [GBM 2011]. The requirement for a notional zero carbon score on every site leads to perverse efficiency measures being required for sites less suited to on-site renewables.

One could of course accept that modelling is never a predictor of actual performance and be content that the actual energy balance will be roughly zero. In the words of George Box ‘all models are wrong, some are useful’. The first problem for our example is that if the heat energy demand turns out to be higher than expected, then our zero emission building will be consuming additional electricity from the grid with three times the $CO_2$ impact than if the building had been heated with gas. Given that it is not considered unusual in the UK for actual energy use for non-domestic buildings to be two or even three times what is predicted, this is a serious concern [Bordass 2004].

It is interesting to consider what happens if we compromise our zero carbon building and retrofit a gas boiler to provide space and water heating. Now for every kWh of gas burned to deliver heat, we save (accepting for a moment the simplistic net zero accounting) nearly three kWh of gas or other fossil fuel at the power station because of the electricity we are now exporting rather than consuming.

In practice the calculation is much more complex than this because the PV generated electricity we are now exporting when the sun shines, cannot be guaranteed to actually prevent the burning of fuel at the power station, due to the complexities of the interactions with the grid. This highlights a weakness in the net zero carbon concept rather than in the thought experiment.

By switching from ‘generate my energy now!’ electric heating to storable gas, we offer another important advantage: we reduce the peak demand on the grid on cold, dark windless mornings, when grid $CO_2$ emissions and demand are likely to peak but our PV panels are producing nothing. By failing to reduce peak demand, no amount of PV will help keep the lights on as power stations are decommissioned; other capital must be found to pay for the required storage or generating capacity.

The need to achieve the Passivhaus primary energy target of <120 kWh/m$^2$ in the above projects should have ensured high levels of thermal efficiency because of the fuel factor of 2.7 applied to the electricity. Other non-Passivhaus projects have claimed the same zero carbon performance but with a much lower building energy efficiency, simply choosing to add additional on-site generating capacity, usually grant funded or feed-in tariff-aided.

This raises the question, which has the lower emissions, a zero carbon Passivhaus or a zero carbon low energy building?

# 3 Biomass as Zero Carbon

Whilst seen by some as an exemplar, a PV electric building might be dismissed as extreme. A more common approach is to use PV for the electrical demand but a cheaper biomass boiler to supply heat. The usual assumption is that biomass is a zero or low carbon fuel. This handy oversimplification is used to short-circuit a raft of prudent design decisions. After all, if you accept the near zero carbon rating of biomass, almost any sort of building could be classed as zero-carbon if it has a big enough boiler.

The low carbon status of biomass and other biofuels has been questioned elsewhere including by the author [e.g. Clarke 2010]. When we burn wood pellets, plant derived oil or biogas the $CO_2$ exhaust emissions are comparable with burning fossil fuel equivalents. What is different is that the $CO_2$ released is part of the present day biosphere carbon cycle, which may be balanced by concurrent growth in a well-managed biofuel system. Again simplistic accounting does not capture the whole picture. Allowances can be made for transport and processing but these are not the fundamental problem

To consider biofuel-burning buildings as zero carbon we have to draw our system boundary to include exactly the right amount of cropland to balance what we burn. This is a theoretical boundary that cannot be drawn on a map or plan. And indeed, if our system boundary is too large we could inadvertently end up with a carbon negative building! Other complications include the time lag between burning and subsequent sequestration, the opportunity cost of using more than your ‘share’ of fuel, given that supply is finite, leaving others obliged to continue burning fossil fuel; and the opportunity cost of burning a crop rather than using it for something else which might, for example sequester carbon in durable structures or make more efficient use of the potential energy by providing heat and electricity with CHP.

Defining the building emissions in this way leads to the paradox that adding extra oil based insulation or heat recovery ventilation apparently increases the building's life cycle emissions, since those measures have additional embodied and, or operational carbon and yet save fuel that is assumed to be zero carbon. If an energy source is truly zero carbon and effectively limitless in supply (imagine a small house sat on a hot spring), then this conclusion is sound, and we should not waste resources on expensive measures to save free energy that would otherwise be wasted.

Even if our energy source is, for the sake of this thought experiment, genuinely zero carbon but in limited supply (e.g. sustainably produced biofuel or renewable electricity) then every kWh used is not available for someone else to use.

# 4 Practical Issues

There are many practical problems with the on-site energy generation that underpins the net zero concept. The inefficiencies of small scale wind or solar on sheltered or shaded building plots and the reliance on building users to provide maintenance and repair, are just two of the many practical issues.

# 5 Future Technologies

The argument in this paper does not depend on the technological or market maturity of technologies such as PV, micro-wind or biomass boilers. PV is getting cheaper and more efficient but we still have to ask the question, are (new) buildings the best place to install them and are householders and busy school caretakers the best people to manage and maintain such technologies? Who is liable for the additional expense when a roof needs repair? What happens when a neighbour plants trees or a new high-rise building goes up? This happened at London's CEREB, the *Centre for Efficient and Renewable Energy in Buildings* (sic) when their new own extension shaded their large roof mounted PV array.

Any installation of renewable energy systems needs to be informed by the appropriateness and cost effectiveness of the site and technology, in the context of national energy policy, economics and grid capacity. None of this has anything to do with the energy balance of the buildings they are bolted to.

If zero carbon buildings are assumed to be the answer then we are forced to devise clever autonomous building solutions such as electric car batteries used to buffer PV output or smart controllers that use electricity when grid $CO_2$ is lowest. However any such innovations, if proven to be sound, can be applied at a more cost effective scale, independent of the zero energy-building concept and should be judged on merit rather than on their fit with the sound-bite of zero carbon. Such solutions should not be limited to the small amount of new-build that comes under the zero carbon regulatory umbrella.

Non-technical solutions to the problem of achieving zero carbon buildings include the concept of ‘allowable solutions’ as proposed in the UK. The idea is that some efficiency should be done first, then some on-site renewables then some as yet to be defined allowable offsite solutions to make up the balance. The potential for unintended consequences and game playing is not difficult to imagine although we can expect the market to provide a plethora of ‘solution providers’. The logical extrapolation of this idea is to levy a carbon tax on all new buildings to be invested where it can be more efficient and will have most impact.

# 6 A Simple Solution

As with models, all boundaries are wrong, some are useful. When considering carbon emissions or energy resources we should arguably consider a global system boundary to account for all emissions and sequestration. That is unworkable as a basis for everyday design decisions.

If we simply define our boundary to include the building and consider any renewables to be part of the national energy pool, then many of the above paradoxes are solved. If we chose to generate electricity from sun, wind or water then that is nothing to do with the building but will instead contribute to the lowering of grid carbon intensity. Just because we are lucky enough to be building next to a river with a small hydro plant doesn’t make our building zero carbon. If we switch to electric heating this increases global emissions rather than reducing them, even if the turbine is within our country’s currently agreed on-site-zero-carbon distance from the building!

Although the reasoning is different, the PHPP already goes some way towards this way of accounting by setting energy use targets and by reporting PV generated electricity separately rather than subtracting it from the Primary Energy value. However biomass is credited as very low carbon when in fact its emissions during combustion are comparable to other solid fuels.

Solar thermal heat cannot be exported and so can most usefully be included as part of the building energy balance as it is now, like a window.

# 7 Conclusions

I propose that energy demand targets are set for buildings, independently of any renewables that might just happen to be located on site, nearby or otherwise linked to the building through supplier agreements or *allowable solutions*. Abandoning the concept of the ‘net zero building boundary’ would drive optimisation of buildings to use less energy whilst freeing up finite resources for more cost effective large scale renewables and energy efficiency retrofit programmes. The primary energy or carbon factor for sources of energy consumed by the building should reflect the average pool value for equivalent fuels. For electricity this would be the connected grid value regardless of on-site generation capacity.

For biogas we would use the national average of biogas and fossil gas. Similarly for oil and solid fuels such as wood pellets we would use primary energy and carbon factors based on the national average of fossil and renewable fuels. Since the renewable fraction is low we can start with the fossil fuel values as a good approximation.

These changes would correctly reflect the reality of design decisions relating to efficiency measures and fuel choice at the building scale. This approach also makes such decisions far less sensitive to assumptions about the interaction of the grid with micro-generation or the correct fuel factors to apply to various forms of biomass or biofuel. With this approach it makes little difference to our design decisions whether biomass is considered to be zero carbon or equivalent to coal; burning less of either results in similar reduction in building emissions. To be clear, this does not mean that it is acceptable to burn coal to heat a building, it means that if we burn wood then someone else does not have the opportunity to use that wood. In rural Austria it might be unthinkable to use anything other than wood to heat our Passivhaus. This is fine, but let us not kid ourselves it is zero carbon.

# 8 Acknowledgement

At the risk of missing people out, I would like to thank Alan Clarke, Kate de Selincourt, Peter Harper, Peter Warm, Judith Thornton, David Olivier, Chris Herring, Mark Siddall, Wolfgang Feist and Andrew Warren, for engaging in debate about these issues over many years.

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