634: Environmentally Sensitive Building Extensions and the Progression to Zero Carbon Existing Buildings

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Abstract.
Improvements to building performance and energy use are necessary to reduce impacts of global warming and rising fuel prices. Much legislation and regulation is concerned with the design and performance of new buildings, particularly dwellings, however replacement of building stock is very slow. As a result more effort is needed to address issues of energy use in existing dwellings. This paper surveys the current position with regard to regulations and also the potential for improving performance of existing dwellings when adding extensions. A case study is introduced and analysed. Some key issues are identified and recommendations for future developments are made.

Keywords: building; extensions; energy, zero-carbon; regulations

1. Introduction.

Events of recent years have suggested that the predicted global warming of the planet is taking place, and that efforts to reduce this, are not proving effective. In additional to the environmental impacts of changing climate, fossil fuel prices are also fluctuating quite widely and have experienced rapid increases in recent times, causing much hardship. Use of conventional fuels will have to change, and carbon intensive applications reduced or curtailed.

The IPCC [1] has identified buildings as one of the major users of energy across the planet and also a sector in which large improvements can be made at zero or even negative overall cost. Some countries have already made excellent progress in improving performance of the building stock and in introducing renewable energy use into buildings and building related activities.

A problem exists in relation to existing building however as their longevity and slow rate of replacement (typically 1% per year in the UK) means that many poorly performing structures will exist for decades to come. This problem is particularly prevalent in dwellings.

An opportunity to improve performance occurs however when an existing dwelling is extended or improved, and this situation has been investigated in a practical way in the research carried out for this study.

The situation described is based upon UK experience in which energy and environmental performance of buildings has largely been driven by requirements set out in the Building Regulations and legislation of its constituent nations. Though these regulations have been less than ideal in the past, they have improved in recent years and are now setting out aims for overall zero-carbon emissions in new buildings, though not existing ones, by 2016.

2. Building Regulations

The primary way in which improvements to building safety and quality standards have been enacted in the UK has been through use of Building Regulations. These first appeared in a rudimentary form following the Great Fire of London of 1666, as an attempt to avoid further tragedies resulting from spread of fire. These regulations applied in London and were further expanded in the 1770s. By the early 1800s other cities such as Bristol and Liverpool had invoked similar regulations.

In the 1840s attempts were made to construct national legislation dealing with structural issues, sanitation, and resistance to fire, but in the event progress was still confined to individual cities.

During the remainder of the 19th Century a number of other pieces of legislation affecting building design and construction came into force, mainly arising from public health concerns. These requirements were generally enacted by local bye-laws created by individual towns and cities.

Edwin Chadwick, a key and vocal advocate for public health reform was one of the first to suggest laws should deal with such elements as insulation, glazing, ventilation and damp-proofing. Little advance on these themes occurred until the 1920s and the formation of the Building Research Board (the forerunner of the BRE), which stimulated more methodical investigation of standards. Application of standards was still variable however and though there was recognition of the need to address many issues in a more unified way it was not until the 1960s that the Building Regulations Advisory Committee (BRAC) appeared.

In 1965 the first truly national Building Regulations were published in the UK (coming into force in 1966) under fifteen headings which included ventilation and heat production.

During the 1970s the need for improvement and recognition of different scales of buildings became apparent, but it was not until the 1980s that meaningful improvements to standards for insulation and ventilation were introduced. The 1985 Regulations were of a changed format and 12 booklets of technical guidance (one for each of the then existing topic areas) were produced to support implementation.

By the 1990s the flaws in the regulations relating to energy conservation were becoming very apparent and began to be addressed through amendments to the 1991 edition of the regulations. Regulations concerning energy performance also began to be applied when work was carried out to modify existing buildings.

Concerns over energy security, fuel poverty and particularly climate change, have forced a much more rapid pace in the change of regulations in the current decade. These changes were accompanied by the introduction of assessment and rating schemes such as the Standard Assessment procedure (SAP) for energy rating [2], and versions of BREEAM (the Building Research Establishment's Environmental Assessment Method) [3].

Recent changes have flowed from the adoption of the European Directive on the Energy Performance of Buildings [4]. This requires the performance of energy assessments and checks on systems as well as schemes to produce energy certificates. In 2007 the Code for Sustainable Homes [5] was introduced in England; though originally an optional form of assessment which evolved from Ecohomes (the version of BREEAM for housing), it is now becoming a mandatory instrument.

The Government requires a 25% improvement in carbon emissions over 2006 levels by 2010; a 44% improvement by 2013; and 100% by 2016. In other words the expectation is that all new homes will be 'zero-carbon' by 2016, all driven by the Building Regulations. A number of critics doubt the ability to meet the target in the current way in which it is set out (especially regarding the generation of renewable energy); however it sets the scene and an ambitious target for the next eight years.

It is through Building Regulations that the base line for changes to the environmental performance of existing dwellings (and extensions attached to them) is also being developed, and the guidance has become more specific with two technical booklets (Approved Documents) dealing specifically with these topics [6], [7], A number of organisations have been active in making proposals for improvement along with supplying good technical advice and developing assessment tools. Examples in the UK are those produced by the Energy Saving Trust [8] and [9]; and from the Building Research Establishment [10]. Academic texts have also provided useful insights [11]. However, many outputs have failed to encompass examination in real practical settings of ongoing projects in which energy efficiency was not necessarily a prime motivator. The theme of improvements to existing dwellings will now be considered in more detail.

3. Application of Regulations to Existing Buildings and Extensions

There is no published policy at present to indicate that regulations designed to achieve zero-carbon status for new dwellings will be applied to existing dwellings. This may not always be the case however and undoubtedly there will be incentives and expectations that energy consumption will be driven down.

The UK Government is already beginning to review options and possibilities [12]. It is also expected that the implementation of the European Directive will aid in the process. This obliges owners of dwellings to have Energy Performance Certificates when properties are sold or newly rented (coming into force during 2008). These ought to have an impact on the market as future owners and occupiers will have a greater interest in fuel and energy costs and impacts on the environment (either because of rising fuel prices or environmental awareness). Rating certificates have been seen to have effects on buyer choice elsewhere, such as the Energy Star scheme pioneered in Austin, Texas in the mid 1980s.

The Building Regulations documents are also more specific and more widely applicable to the upgrading of existing dwellings. When significant alterations are made it is necessary to consider if not just new additions need to meet standards but also if there are implications for the building as a whole. Of course complying with regulations should be start point, not an end point and particularly in the case of significant extensions, all opportunities should be considered since there will already be disruption caused by the building work and additional improvements will cause less inconvenience.

Current building regulations applied to existing dwellings are also primarily concerned with energy use and conservation whilst the Code for Sustainable Homes has a wider environmental remit including emphases on such topics as building materials.

4. Opportunities for Improvement through Extensions

When considering the range of potential improvements to existing dwellings it is necessary to distinguish between features that are amenable to alteration and those which are not. For instance changing the site, position, topography, location of surrounding buildings, and orientation (all of which may offer opportunities for improvement for new developments), cannot easily be varied in existing dwellings.

Components which may be influenced however are:

- built-in adaptability for future changes in use patterns;
- thermal insulation (in walls roofs, floors);

- reduction of cold bridging and detailing, including connection to existing dwelling;
- type and location of windows;
- use of shading and wind breaks;
- ventilation strategies and heat recovery;
- exposure of thermal mass;
- zoning and upgrading of heating, hot water and control systems;
- insulation of tanks and pipe work;
- water harvesting and reduction in run-off;
- low water use appliances, taps, showers;
- choice of environmentally sensitive building materials and construction techniques;
- addition of renewable energy devices; and
- development of advice and information for occupants to help them use the building and its systems more efficiently.

The positioning of an extension can also have implications for energy use: it may generally be located on the front or rear elevation, and in circumstances such as semi or fully detached houses, the side also. Figures 1, 2 and 3 illustrate these options. Improvements may also be made through addition of loft or roof extensions though these are perhaps a more specific case because of the major interaction with a single element of the building.

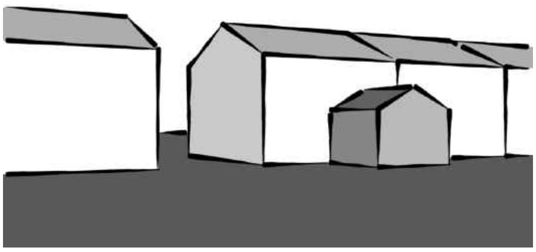

Figure 1: Front elevation extension

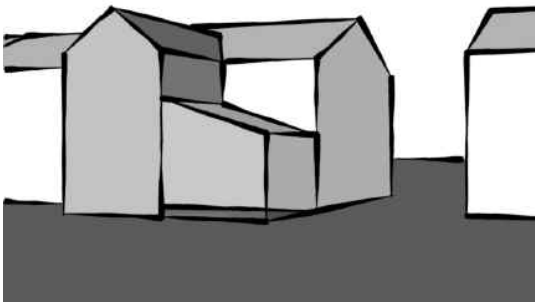

Figure 2: Rear elevation extension

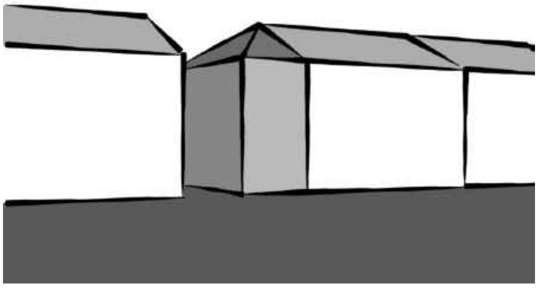

Figure 3: Side elevation extension

In many cases planning guidelines will restrict the amount of development on the front elevation to a rather modest size. Side elevations may also be limited by width of plot and impact on neighbours. The more common extension through which major impacts may be made is often at the rear but of course this then limits opportunity depending on the orientation of that façade.

Reports such as [12] indicate that the best opportunity for carbon savings for existing dwellings come from improvements to heating systems through the installation of more efficient appliance or use of renewable technologies. Renewables that produce electricity also have benefits as they are normally replacing a more carbon intensive energy source.

If a dwelling is to be extended or substantially modified however the secondary issues of reducing initial demand through better insulation and conservation measures assume greater significance. This occurs because in dwelling not undergoing building extension work there is considerable inconvenience from engaging in upgrading of the building fabric. There is also the opportunity in extending a dwelling to partly or wholly envelop the portion of the existing structure which is most weak from a thermal point of view (typically at least one wall of the dwelling, perhaps and also in the sub-floor area and across roof-spaces).

In aiming to achieve zero-carbon or close to zero-carbon, for existing dwellings (which should be a long term aim) it is likely however that energy demand will still have a residual and significant component from the existing structure, and as such renewable sources will be required. A problem in this respect lies in the emphasis in current plans for on-site generation of energy, particularly electricity. In urban areas the external space and building façade elements required to permit such generation are very limited (especially considering planning guidance leading to significantly higher density of building). This has led some to suggest alternative means of satisfying the need for low carbon solutions in high density cities [13]. Many similar arguments might be applied to the means for improving existing buildings.

5. Case Study

In order to further examine the opportunities for improving energy performance and commencing movement to the goal of zero-carbon buildings, a study was carried out on a live project. This project was a significant extension to an existing and rather complex semi-detached house located in the south of the UK. The owner was keen to invest in environmental measures but the shape and form of the structure made the solutions somewhat complicated. The main design issues and solutions demanded significant research and investment of time – the detailed processes of which there is not sufficient space to describe here. The following paragraphs therefore summarise the design decisions taken.

The layouts and elevations were influenced by the clients, existing conditions, and sustainable design principles. As with all existing dwellings the orientation was fixed, but this led to a re-ordering of spaces to better use the solar gains. Exploitation of thermal mass to reduce temperature fluctuations was restricted due to the need to use internal insulation to maintain the external appearance of the dwelling.

Two green roofs were incorporated as part of developing an environmentally conscious building whilst also reducing the ecological footprint of the dwelling.

Mechanical, electrical and water services are an important part of an environmentally conscious house but were restricted in development in this particular case due to external factors. There are plans however to harvest water collected from the zinc and slate roofs to use as grey water for flushing of toilets etc. There is adequate room either in the basement storage areas or empty loft spaces to house a domestic sized water storage tank.

A consideration not yet decided is the use of solar water heaters; an area of $5m^2$ of panel is generally adequate for a domestic sized property, and it could be sited on the south facing green roof.

During the specification process for materials the requirements of the clients and designers lead to some compromises, one of these being the zinc roof. A more environmentally friendly material, such as a form of reclaimed tile could have been used; however, the aim was to create a distinctive difference between the old and new, which lead to the idea of a standing seam roof.

The upgrade of the existing walls and roof proved difficult to improve on U-values whilst maximising the internal floor space. The existing masonry wall for example, was calculated to achieve a U-value of $0.25W/m^2K$ with the use of insulated plasterboard; an alternative to this would be to use thin thermo-reflective insulation, to reduce the U-value to $0.16W/m^2K$.

The materials chosen were specified with reference to green materials guides, in order to reduce embodied energy and carbon footprint. Where possible, a manufacturer was specified, however local availability of materials also has to be considered.

Figures 4, 5 and 6 illustrate some aspects of the building

Figure 4: Front elevation of case study building extension

Figure 5: Rear elevation of case study building extension

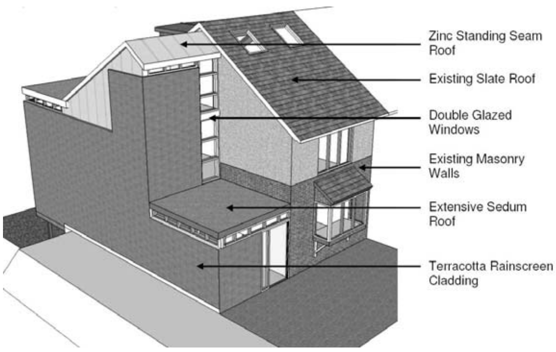

Figure 6: Case study building extension showing some of the elements incorporated features

6. Energy Evaluation

Studies to investigate potential energy improvement impacts were performed using a simulation modelling techniques. There is insufficient space here to report in detail upon the findings however comparisons between alternatives were possible.

Following close examination of the development of the extension case study the following suggestions have been produced to optimise performance:

1. Passive solar design and zoning is compromised because existing homes have a fixed orientation but re-ordering of internal spaces can maximise solar gains and minimise heating requirements. This showed as a clear benefit from the evaluations carried out.

2. Insulation has great ability to reduce energy use and hence CO_2 emissions from whatever source. Following upgrade, all external elements should combine to give an average U-value no greater than $0.20W/m^2K$ for existing properties, but ideally less. In studies performed, the energy saving benefits of such upgrade is of the order of 50% however difficulties in matching up to existing construction detailing were evident - particularly when insulation levels (and consequent thicknesses) exceeded these values.

3. High performance glazing should be used with low-e coatings and gas filled units. Frames should be timber or use thermal breaks. There are few reasons in refurbishment using new window units why such standards should not be observed as a matter of course.

4. Thermal mass - high density materials should be utilised to decrease internal temperature fluctuations. Existing concrete/stone walls should be left exposed, and external (rather than internal) insulation should be used where possible. Studies into housing performance under warming climate scenarios have indicated the need in moderate climates to incorporate higher levels of thermal mass into new builds. Though in some places with already moderately high summer temperatures it may not be possible to avoid the need for some active cooling; in other localities, the increase in use of thermal mass may be able to do so.

5. Aim to create an air tight envelope as air leakage is a major cause of heat loss - external openings and component joints should be sealed where possible, e.g. windows, doors, services, and internal finishes. All seals should be durable and impermeable. Air leakage should be less than $1m^3/hr/m^2$. Whilst it is easy to define such standards there can be problems in achieving them in practical situations of refurbishment and extension. This arises from mismatches in materials and dimensions. Extra care with detail design is therefore needed along with careful site supervision to reduce unwanted infiltration.

6. Existing thermal (cold) bridges should be insulated; care must be taken to avoid these around external openings. Again this can be difficult to achieve with extensions to existing properties because of constructional issues.

7. Special care should be taken at junctions between existing dwelling and new extensions to maintain a weather and air tight envelope, allowing for settlement of the new structure, and without compromising the thermal properties of the adjoining structure through cold bridges

8. Whilst space heating should be minimised through solar design, thermal mass, air tightness and removal of cold bridging, energy efficient boilers or heat sources should also be utilised. Mechanical ventilation heat recovery systems with summer bypass should be implemented. The evaluation indicated that improvements in energy efficiency in excess of 10% should be possible.

9. The new structure should be adaptable to aid the longer term sustainability and use - internal spaces should be designed to be as adaptable as possible, to meet future occupant requirements. This can be contradictory to the requirements to achieve item 1 above, but can be achieved through individual zone control linked to heating systems that can adapt to new needs.

10. Renewable energy - solar water heaters should be installed and alternative sources considered such as heat pumps (if powered by renewable electricity). A full analysis is needed however to optimise performance and also to incorporate cost-benefit analysis.

11. Rainwater should be collected and used for flushing toilets and for watering the garden, so to reduce wastage of potable water and save energy costs in production of mains supplies.

7. Materials Evaluation

Though the primary aim of this paper was to examine means to reduce energy use and carbon intensity, it became clear through development of project ideas that materials use was also a very significant factor. As a result suggestions are also made in this area.

1. Each component's embodied energy should be assessed, using verified manufacturer information or established guides.

2. Local sourced materials should be specified over others of a similar performance from further distance.

3. Where possible, materials should be reused from site or reclaimed to reduce the need for virgin materials.

4. Recycled content - If a product has to be bought new it should contain some recycled content, preferably a higher percentage than for new materials.

5. Reduce the quantity or wastage on site by rationalising the design of a building to align with product dimensions or considering the use of pre-fabricated elements.

6. Include recycling facilities on site and segregate waste.

7. Timber must be sourced from sustainable managed forests and certified from regulatory bodies.

8. Instead of the commonly used building materials and techniques, consider greener alternatives, such as green concrete by using lime cement and use recycled aggregates.

9. Organic derived insulation should be specified if available and suitable, alternatively inorganic Forms may be used.

10. Special care should be taken when specifying different materials at the junction of old and new, to avoid later settlement issues and material incompatibilities.

11. Time and care should be taken to achieve a detailed specification, including accurate product naming, (not 'or similar approved' material sourcing), and techniques in which the components are fabricated should be properly specified.

8. Conclusions and Recommendations

The issue of reducing carbon emissions from existing buildings is one which many countries of the world have yet to address. Most have shown concerns for upgrading of new build properties but few have found effective measures for those already existing.

This study has attempted to explain some of the issues and consider ways forward. It has also allowed exploration of real issues and problems in the context of an existing building for which a substantial extension has been proposed.

In developing low carbon solutions it is also important to consider the role of building materials and how overall construction can become more environmentally sensitive – something which again is being dealt with in standards for new property but less so for existing. Recommendations have been made for both energy and materials use issues.

In the UK the Code for Sustainable Homes has signalled intent for new build dwellings and it seems timely to consider if and how similar advice can be developed for existing dwellings. This would be particularly appropriate for those undergoing extension as opportunities to modify major building components and services exist in such circumstances.

It may also be necessary for incentives to be offered as the costs for engaging in retrofit into existing buildings are potentially higher than for new build.

What is certain is that these issues require attention in the near future and that ignoring them stores trouble for the longer term and increases risks of fuel poverty and supply security.

9. References

1. Levine, M., D. Ürge-Vorsatz, K. Blok, L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling, H. Yoshino, (2007), Residential and commercial buildings. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

2. DEFRA (2005). *The Government's Standard Assessment Procedure for Energy Rating of Dwellings* [Online] Available: http://projects.bre.co.uk/SAP2005/pdf/SAP2005.pdf [13 June 2008]

3. BRE (2006). Ecohomes 2006 – The environmental rating for homes The Guidance – 2006 Issue1.2 [Online) Available: http://www.breeam.org/filelibrary/EcoHomes_2006_Guidance_v1.2_-_April_2006.pdf [13 June 2008]

4. European Commission (2003) *Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings*, OJ L 1, 4.1.2003, p. 65–71

5. DCLG (2007). *Code for Sustainable Homes – Technical Guide.* Department for Communities and Local Government. [Online] Available: http://www.communities.gov.uk/publications/planningandbuilding/codeguide [13 June 2008]

6. ODPM (2006), *The Building Regulations 2000, Approved Document Part L1B, Conservation of Fuel and Power in Existing Dwellings*, NBS, UK.

7. ODPM (2006), *The Building Regulations 2000, Approved Document Part L2B, Conservation of Fuel and Power in Existing Buildings other than Dwellings,* NBS, UK

8. Energy Saving Trust (2007). *Energy efficient refurbishment of existing housing,* Energy Efficiency Best Practice in Housing guide CE83, Energy Saving Trust.

9. Energy Saving Trust (2005). *Energy efficient domestic extensions,* Energy Efficiency Best Practice in Housing guide CE122, Energy Saving Trust.

10. Building Research Establishment, *BREEAM Ecohomes XB (2008),* [Online] Available: http://www.breeam.org/page.jsp?id=25 [1 Sept. 2008]

11. Smith, P.F. (2004). *Eco-refurbishment: a guide to saving and producing energy in the home,* Architectural Press.

12. DCLG (2006). *A Review of Sustainability of Existing Dwellings*. Department for Communities and Local Government. [Online] Available: http://www.communities.gov.uk/publications/planningandbuilding/reviewsustainability [13 June 2008]

13. Sullivan, L., B. Mark, and T. Parnell, (2006): Lessons for the Application of Renewable Energy Technologies in High Density Urban Locations. In *Proceedings PLEA2006 23rd Conference on Passive and Low Energy Architecture*, Geneva, Switzerland.