Future-proofing the energy performance of English dwellings

Maria-Christina Georgiadou

ABSTRACT

This paper examines the concept of building for the future or 'future-proofing' as an unexplored yet all-important aspect in the design of low-energy residential buildings. It refers particularly to adopting lifecycle perspectives and accommodating risks and uncertainties into the selection of energy efficiency measures and low carbon technologies. A case study method is followed and data is gathered from two 'best practice' housing developments in England; i.e. 'North West Cambridge' in Cambridge and 'West Carclaze and Baal' in St Austell, Cornwall. These two projects are assessed against a set of future-oriented design criteria and assessment methods, which, in turn, provide 'best practice' guidance for 'future-proofing' the energy performance at an early design stage.

Keywords: Dwellings, Eco-communities, Energy, Future-proofing, Lifecycle, Risks, Uncertainties.

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1. Introduction

The energy use of the domestic stock in the UK has changed rapidly over the past 50 years [1]. Given that buildings provide the potential for achieving long-term, significant and cost-effective Greenhouse Gas (GHG) emissions reductions, the Government has set out an ambitious target for all new homes to be zero carbon from 2016, followed by an 80% cut in the entire building sector by 2050 [2]. However, the UK has amongst the oldest and least energy-efficient homes in Europe accounting for about 30% of national GHG emissions [3]. Traditional building design is based primarily on standard practice or intuition assuming that buildings will never experience significant change, even though the type and pace of future requirements may be wholly different compared to past experience [1, 4]. Little research has been conducted into designing low-energy dwellings which are able to accommodate explicitly future social, technological, environmental, economic, and policy trends. This paper explores the potential for future-proofing the energy performance of residential buildings from the energy design stage.

2. Methodological approach and justification for research

A case study method is followed, which focuses on two 'best practice' eco-communities in England; i.e. North West Cambridge in Cambridge and West Carclaze and Baal in St. Austell, Cornwall [5-6]. Empirical data is gathered to examine how the energy design of dwellings incorporates a set of criteria and assessment methods for achieving future-proofing [7]. The data collection is centred on the selection of energy efficiency measures and low carbon technologies; i.e. micro-generation or district networks. The data collection protocol includes document analysis, semi-structured interviews and focus groups[1]. Three technical documents that formed part of the Outline Planning Application have been reviewed for each case study; i.e. Sustainability Statement, Energy and Carbon Strategy, and Design and Access Statement. Due to their high sustainability standards, these projects are expected to provide the best platform for understanding the practicalities and proposing guidelines for achieving 'future-proofing'.

3. Conceptual framework for future-proofed energy design

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[1] To date, ten interviews and focus groups have been carried out and the target group includes senior planning officers, developers, energy consultants, and architects involved in the energy design of these projects.

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3.1. Definition

Georgiadou *et al.* define future-proofing as "stress-testing building solutions against a range of possible futures" [7]. The objective is to ensure that the energy design remains functional over the lifecycle and able to accommodate changing circumstances. A low-energy building does not necessarily constitute a future-proofed one, but does represent a point of departure from which to further develop this concept [8]. There are two key features that enhance long-term thinking in relation to the energy performance of dwellings, which need to be considered from the energy design stage [7]:

- Adopting a full *lifecycle perspective* to minimise the environmental impacts of building solutions from "cradle to grave".
- Accommodating *risks* and *uncertainties* to adapt to the occurrence of high-impact and unpredictable events, which can affect the energy consumption.

3.2. Design criteria and assessment methods

A thorough literature review is undertaken to develop the criteria for future-proofing the energy performance of dwellings at an early design stage. This overview covers the areas of: low-energy buildings and sustainable energy in urban settlements; trends and drivers affecting the energy use in buildings and cities by 2050; climate change adaptation and mitigation; and established building energy assessment methods. This overview reveals the design criteria and assessment methods presented in Table 1 [7, 9-13].

Table 1. Design criteria and assessment methods for future-proofing the energy performance of dwellings

'Future-proofing' requirements	Design criteria	Assessment methods
Lifecycle perspective		
Gap between the design and actual energy performance	Conduct systematic monitoring and provide feedback during the operational stage	Post Construction Audit Post Occupancy Evaluation
Design for longevity	Design for deconstruction rather demolition; i.e. disassemble for re-use and recycling	Embodied energy calculations Sustainable procurement Material selection based on accredited databases
	Minimise the environmental impact of key components (e.g. walls, floors)	Lifecycle Assessment
Shift away from capital cost assessment of project financing	Assess the lifecycle cost and benefits	Lifecycle Costing
Accommodating risks and uncertainties		
Climate change and temperature increase	Accommodate the risk of overheating that may damage the fabric, increase the energy consumption and the need for mechanical cooling	Dynamic overheating analysis with stochastic weather files
Consider: Occupants' changing behaviours Technological innovation Higher energy prices More stringent building regulations	Impede the use of steady-state models Design for internal space flexibility to avoid disruptive upgrade and technology 'lock-in' phenomena Outperform statutory minima	Dynamic energy modelling Lifetime Homes standard Building for Life standard Code for Sustainable Homes[2]
"Unknown unknowns"; i.e. occurrence of unforeseeable events	Plan for a spectrum of plausible futures	Futures techniques (e.g. Scenario Planning, visioning, backcasting)

[2] The Code for Sustainable Homes is an environmental assessment tool for rating the performance of new homes in England. It became legally binding in 2008 and is the single national standard to drive innovation towards achieving zero carbon new homes by 2016. Since 2010, the minimum statutory requirement is Code Level 3, rising to Level 4 in 2013 before finally moving to zero carbon (Level 6) in 2016 [14].

4. Case study research

4.1. Description

The *North West Cambridge* site is an area of around 141ha located on the edge of Cambridge [5]. The vision is to create a new mixed-use eco-quarter, which will contribute to meeting the needs of the University and the wider city up to 2021 and beyond, together with embodying best practice in environmental sustainability. With regard to the domestic stock, the planning application provides for 1,500 private houses and 1,500 homes for University staff and student accommodation. In terms of climate change and energy consumption, all dwellings have to meet the target Fabric Energy Efficiency Standard (FEES)[3], the national Code for Sustainable Homes (CSH) Level 5 and there are also provisions for decentralised energy generation [ibid].

The China Clay Area in Cornwall was one of the four first eco-towns identified in 2009 [6]. The vision was to regenerate the existing post-industrial settlements to help address the decline of the mining operations in the area. Although the coalition Government has altered the eco-town initiative, the key principles of the regeneration plan are still promoted by the Cornwall Council with the *West Carclaze and Baal* site being the first eco-community proposal. This is a mixed-use development of 310ha including 2,000 dwellings with 40% affordable housing. All homes will achieve the FEES as a minimum and CSH Level 4 and above [ibid].

In terms of the energy design, both developments follow a hierarchical process; i.e. fabric first approach with energy efficiency measures to meet the FEES target, followed by the use of low carbon technologies to meet the residual energy demand.

4.2. Synthesis of results

This section reveals the extent to which the selected exemplar case studies integrate futures thinking into the energy design of dwellings. The analysis follows the two distinctive features of future-proofing; i.e. adopting a lifecycle perspective and accommodating risks and uncertainties

4.2.1. Lifecycle perspective

According to an energy consultant respondent, future-proofing is about “a developer that remains involved at a post-construction stage for ongoing monitoring purposes”. Both projects have been designed for a long development phase of 20-30 years and the participants agree that the lifecycle perspective refers both to the fabric performance and occupants’ behaviour. North West Cambridge is a University-owned land; hence, this is similar to the case of developing on publicly-owned land. In contrast, the West Carclaze and Baal site is developed by Eco-Bos, a joint venture between Imerys Minerals Ltd and Orascom Development Holdings. Unlike typical house builders that focus on selling homes, Eco-Bos has a lifecycle view on the site and will be involved in the operation and maintenance of dwellings with the results informing the next design stage. Table 2 shows how the two projects perform in terms of the energy-related criteria and assessment methods that help maximise the useful lifetime of homes.

Table 2. Evidence of lifecycle perspectives in North West Cambridge and West Carclaze and Baal

Case study / Future-proofing Requirements	North West Cambridge	West Carclaze and Baal

[3] According to the Zero Carbon Hub recommendations, the Fabric Energy Efficiency Target is $39kWh/m^2/yr$ for apartment blocks and mid terrace properties and $46kWh/m^2/yr$ for semi-detached and detached houses [13].

Post Construction Audit Post Occupancy Evaluation	Yes Co-heating tests, thermal imaging, and occupant surveys	
Design for deconstruction	Requirements for embodied energy calculations Requirements to maximise the potential for re-use and recycling of raw materials currently available on-site during construction A-rated materials based on the BRE Green Guide	Requirements to maximise the use of local materials and suppliers Embodied energy considerations are involved in local procurement but they do not follow any specific calculations or methodologies No particular reference for re-use and recycling
Lifecycle Assessment	No	
Lifecycle Costing	Elementary form: Use of carbon abatement curves/ lifecycle cost for selecting low carbon technologies	Elementary form: Use of Multi-Criteria Analysis for selecting low carbon technologies with criteria for operational and maintenance costs

Sources: From fieldwork data (March 2010 to date).

In North West Cambridge, there are requirements for embodied energy calculations and A-rated environmentally-friendly materials based on the Building Research Establishment (BRE) Green Guide [15]. Nevertheless, in Cornwall key considerations are the need to support local suppliers, local employment, and reflect the Cornish building traditions. This, in turn, influences implicitly considerations for sustainable procurement; however, no mandatory embodied energy calculations or materials selection based on the re-use and recycling potential are required. Lastly, there is no comprehensive use of the Lifecycle Assessment (LCA) or Lifecycle Costing (LCC) methods in both projects.

4.2.2. Accommodating risks and uncertainties

Both eco-communities seek to future-proof their dwellings so as to avoid the vulnerability of an obsolete design against impacts arising from changing circumstances. Nevertheless, Table 3 reveals that neither project adopts a comprehensive approach to future-proofing acknowledging the whole spectrum of criteria and methods presented in Table 1.

Table 3. Evidence of accommodating risks and uncertainties in North West Cambridge and West Carclaze and Baal

Case study **Future-proofing Requirements**	**North West Cambridge**	**West Carclaze and Baal**
Overheating	Passive design techniques (massing, spacing, orientation), insulation, thermal mass, natural ventilation	
	Use of dynamic modelling (IES) based on UKCP09 2050 weather projections	Use of steady-state models (SAP)
Occupants' changing behaviours	Building for Life (under consideration)	Home Office option in all homes Lifetime Homes standard Building for Life Silver standard
Technological innovation (potential upgrades that can be made to the design with minimal effort)	Fuel switch from a gas-fired CHP to a biomass-fuelled in the future Space for a future energy centre	PV-ready roofs Specification for triple glazing Space for energy storage
Higher energy prices due to fossil fuel depletion	Multiple energy sources and no overreliance to a single technology	
	Gas-fired CHP district heating Solar PV	Micro-generation: Solar PV, solar thermal and air-source heat pumps
More stringent building regulations	Outperforming statutory minima	
	CSH Level 5 for all dwellings	CSH Level 4 for terraced and Level 6 for detached homes
Unknown unknowns	No use of futures techniques to plan for a spectrum of plausible futures	

Sources: From fieldwork data (March 2010 to date).

The need to design out future climate impacts and, in particular, overheating due to temperature increase is a common objective; however, the approach differs. In North West Cambridge, the design team has incorporated stochastic weather data, representative of future temperatures, based on UK Climate Projections (UKCP09) 2050 climate scenarios into building thermal simulations [16]. In Cornwall, the energy consultants have not conducted any dynamic overheating analysis to date. Also, both projects demonstrate the commonly-used passive design techniques (orientation, external shading) and energy efficiency measures (insulation, air tightness, thermal mass, natural ventilation) to minimise the need for mechanical cooling and, therefore, reduce the energy use.

West Carclaze and Baal surpasses North West Cambridge in accommodating the changing needs of present and future occupants' into the design of dwellings. Key considerations cater for an ageing population and increased levels for home working in the area. All dwellings have specifications for home-office and will be certified to the Lifetime Homes and Building for Life (Silver) standards to ensure convertibility and expandability of internal space [17-18]. In North West Cambridge, there are some elementary discussions for voluntary certification to the Building for Life Standard. In an effort to future-proof the development both eco-communities are designed to outperform statutory minima. To comply with the Government target, dwellings constructed after 2016 will be zero carbon, thus meeting CSH (Level 6).

An important finding from the interviews and focus groups is that there is no such thing as 'perfect models'. Long-term forecasts can be notoriously erroneous due to the long development phases of these eco-communities. Even when models are perfectly accurate uncertainty still remains, as future impacts can be highly unpredictable due to 'unknown unknowns'. The use of futures techniques is suggested for addressing the wider spectrum of trends and drivers affecting the energy consumption of dwellings by at least 2050 as presented in Table 1. At present, however, both projects do not demonstrate any use of this 'family' of tools.

5. Concluding discussion

The paper has examined how future-proofed is the energy design of two exemplar English eco-communities. This refers to adopting a full lifecycle perspective and accommodating risks and uncertainties that affect the energy performance over the long-term. However, it is important to follow a flexible approach that considers viability issues and does not prescribe building solutions in order not to stifle innovation. Although the building industry is opposed to long lifecycles and changing circumstances, this study gives insight into testing and trialling an innovative concept that encourages multidisciplinary thinking and a systems approach. Focusing on the design criteria and assessment methods for future-proofing, the following conclusions are drawn:

- Full lifecycle thinking can be achieved via POE and design for deconstruction (re-use, recycling, embodied energy considerations). At present, the use of the LCA/LCC tools is challenging and requires further research and market incentives.
- Developers acknowledge predominantly the risk of overheating, occupants' changing behaviours, technological innovation, higher energy prices, and the more stringent policy framework. Future-proofing should involve the use of stochastic models, designing above building regulations and planning for a spectrum of plausible futures to accommodate unforeseeable events, which can be achieved via the use of futures techniques.

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References

1. Ravetz J, State of the stock – What do we know about existing buildings and their future prospects? Energy Policy, 36(12), 4462 – 4470, 2008.
2. Committee on Climate Change, viewed 11 August 2011, http://www.theccc.org.uk/about-the-ccc/adaptation-sub-committee.
3. Boardman B, Darby S, Killip G, Hinnels M, Jardine C N, Palmer J. and Sinden G, 40% House Project, Environmental Change Institute, University of Oxford, 2005.
4. Russell P and Moffatt S, Adaptability of Buildings, IEA Annex 31 Energy-Related Environmental Impact of Buildings, University of Karlsruhe, 2001.
5. South Cambridgeshire District Council and Cambridge City Council, North West Cambridge, Area Action Plan, Development Plan Document, 2009.
6. Buro Happold, West Carclaze & Baal Eco-Community, Energy and Carbon Strategy, 2011.
7. Georgiadou M C, Hacking T, Guthrie P, A framework to future-proof the energy performance of buildings (accepted manuscript). Energy Policy, DOI: 10.1016/j.enpol.2012.04.039.
8. Holmes M and Hacker J, Climate change, thermal comfort and energy: Meeting the design challenges of the 21st century. Energy and Buildings, 39(7), 802 – 814, 2007.
9. Jones Lang LaSalle, From Sandbags to Solar Panels: Future-Proofing UK Real Estate for Climate Change Resilience, London, 2010.
10. Pitts A, Future proof construction – Future building and systems design for energy and fuel flexibility. Energy Policy, 36(12), 4539 – 4543, 2008.
11. Sanders C H and Philipson M C, UK adaptation strategy and technical measures: The impacts of climate change on buildings. Building Research & Information, 31(3 – 4), 210-221, 2003.
12. SEMBE, Powering our Lives: Sustainable Energy Management and the Built Environment, Foresight, Government Office for Science, London, 2008.
13. Zero Carbon Hub, Defining a Fabric Energy Efficiency Standard for Zero Carbon Homes, Task Group Recommendations, 2009.
14. DCLG, Code for Sustainable Homes: Technical Guide – 2010, Department of Communities and Local Government, London, 2010.
15. BRE Green Guide Homes, ‘Guidance Documents’, viewed 5 April 2012, http://www.bre.co.uk/greenguide/page.jsp?id=2080.
16. UK Climate Projections, ‘What is UKCP09’, viewed 30 November 2011, http://ukclimateprojections.defra.gov.uk/content/view/868/531/.
17. Lifetime Homes, viewed 4 April 2012, http://www.lifetimehomes.org.uk/.
18. Building for Life, viewed 4 April 2012, http://www.buildingforlife.org/criteria.