Future-Proofed Design for Sustainable Urban Settlements: Integrating Futures Thinking into the Energy Performance of Housing Developments

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Abstract: This paper investigates sustainable building and low energy housing at a neighbourhood or city district scale. In particular, it examines how futures thinking on the energy performance can be integrated into the selection of building components, materials and low or zero carbon technologies. A multiple case study is undertaken in European housing developments that represent sustainable communities of 'best practice'. A literature review on the need for long-term thinking in the built environment research is followed by the definition of 'future-proofed design' and its application to the energy performance of housing developments. The extent to which building strategies in selected urban settlements have been 'future-proofed' is assessed. The analysis of the case studies includes a set of identified trends and drivers affecting the energy performance of buildings by 2050. The building strategies that explicitly accommodate these future aspects in these projects are also examined. Results suggest that the vast majority of building decisions focus predominantly on cost-effective solutions, such as energy efficiency measures. The use of renewable energy technologies, low embodied energy components, and new methods of construction relate to a demonstration project or any specific regulatory requirements. It is shown that 'best practices' accommodate predictable trends and drivers rather than exploring a wider spectrum of plausible futures. This reveals the tendency to neglect long-term thinking due to the complexity of dealing with uncertainty and the short-term mindset of the building industry. It is concluded that building strategies need to be more flexible to adapt to climate change, accommodate future changes and follow the increasingly stringent building regulations. A new generation of decision-support tools that combine futures techniques with mainstream sustainability assessment methods should also be developed.

Keywords: *Sustainability, Housing developments, Energy performance, Future-proofing, Building strategies.*

1. Introduction

The building sector has the greatest potential to deliver long-term, significant and cost-effective Greenhouse Gas (GHG) emissions compared to other major emitting sectors, such as transport and industry [1]. It is estimated that 64% of the world's economic production, consumption and environmental pollution is associated with the urban built environment in developed countries, where people spend around 80-90% of their time indoors [2-3]. At present, the building sector accounts for around 40% of total energy consumption worldwide, which translates to about 30% of global carbon dioxide emissions [4].

Sustainable development is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' [5]. Sustainable building has emerged as an integrated approach to urban design with the evaluation of social, economic and environmental aspects surrounding the use of natural resources, energy consumption, environmental performance, functional quality, and the consideration of future values [6]. The latter entails the concept of 'future-proofing', which refers to an explicit and systematic appraisal of future possible options. In practice, however, little research has been conducted into the issue of how to design and construct buildings considering long-term implications of the energy performance and carbon footprint, due to the dominant short-term mindset that prevails in much of the property and construction sectors [7].

This paper introduces the concept of 'future-proofed design' and presents its application to the energy performance of European housing developments of 'best practice'. It seeks to assess the extent to which exemplary projects integrate futures thinking into the selection of materials, building components and low or zero carbon technologies. The objective is to uncover building strategies that can 'future-proof' the energy performance of residential buildings against long-term impacts of climate change, technological innovation, demographics, energy behaviours and market forces. The term 'energy performance' refers to energy efficiency, on-site renewable energy generation, and the embodied energy[1] of materials and building components. There is a growing trend towards 'sustainable communities', which refer to eco-developments of various scales, such as eco-neighbourhoods, eco-towns or eco-cities. In this paper, the term relates to urban settlements at the neighbourhood or city district scales that demonstrate pioneer thinking, political leadership, a whole systems approach, innovative financial solutions, low carbon innovation, multi-stakeholder collaboration, and community engagement [8]. Unlike individual buildings, community-led processes offer greater opportunities for a step change in sustainability through the integration of community energy networks and better economies-of-scale for novel Renewable Energy Technologies (RET) [9].

2. Methodology: Case study approach

The research adopts a 'real-life' perspective to understand the opportunities, practical constraints, and trade-offs in the selection of materials, building components and RET. The literature review focuses on the justification and conceptualisation of 'future-proofing'. A multiple case study method is employed in turn and 'best practice' European housing developments from 200 to 11,000 residences are selected. Table 1 provides a list of the case studies, along with a short project description. These projects are expected to provide the best platform for planning and design techniques from which to develop any improvements with regard to 'future-proofing'. Case studies entail both desk-based research and fieldwork. An ongoing survey via a structured questionnaire in parallel to expert interviews and focus groups via a semi-structured questionnaire are carried out since October 2010. The target audience includes planners, developers and local authorities involved in these projects.

3. The concept of future-proofed design in urban settlements

3.1. The need for futures thinking

An underlying reason to 'future-proof' buildings is that design choices cannot be easily revised and that the cost of inaction significantly outweighs the cost of timely action [14-15]. Futures thinking should be systematically integrated into the early planning and design stages, thus avoiding social, economic, and environmental costs associated with modifying settlements once they have been built. 'Although upfront design and construction costs may represent only a fraction of the lifecycle costs, when just 1% of a project's upfront costs are spent, up to 70% of its lifecycle costs may already be committed […] that first 1% is critical because, as the design adage has it, all the really important mistakes are made on the first day' [16].

[1] Embodied energy is the energy used to extract, process, manufacture and transport building materials and components.

Table 1: Selected 'Best-Practice' Housing Developments in Europe.

Project	Description
Hammarby Sjöstad, Stockholm, Sweden [8]	The 2010 European Green Capital. A mixed-use development of 11,000 apartments with energy, waste, and water following a unique eco-cycle. The City's long-term goal is to be fossil fuel-free by 2050.
Malmö, Sweden [10]	Bo01 and Västra Hamnen are two 'green' neighbourhoods (around 600 homes). By 2020, the City aims to be climate neutral and by 2030 the whole municipality will run on 100% renewable energy.
Freiburg, Germany [8]	Vauban (5,000 homes) and Rieselfield (4,200) homes are two district demonstrating pioneer thinking in solar energy.
Hanham Hall, Bristol, UK [9]	The first development of around 185 homes to meet zero carbon standards (Code for Sustainable Homes Level 6) in the UK.
Northstowe, Cambridgeshire, UK [11]	A new carbon neutral town of approximately 9,500 new homes, a town centre, offices and schools at a pre-design stage.
First wave of the Eco-town Programme UK [9,12]	Four new mixed-use developments of around 5,500 zero carbon homes and 40% of affordable housing at a pre-design stage: - Whitehill Bordon, East Hampshire - China Clay Country, St.Austell, Cornwall - Rackheath, Norfolk - Northwest Bicester, Oxfordshire
One Planet Communities UK [13]	- BedZED, London Borough of Sutton: around 100 zero carbon homes and 50% affordable housing. - One Brighton: a new mixed-use development of around 175 zero carbon apartments, office units and community facilities.

Another key motivation for future-proofing is the slow turnover of the stock. Buildings have generally an economic life of 50 to 60 years and a design life of 40 to 100 years [17-18]. Long lifecycles are due to high upfront costs of retrofitting, practical difficulties associated with deconstruction or demolition, and social attachments due to historical or cultural reasons, even if this was not explicitly the intention [19]. However, change is inevitable and caused by operational and maintenance processes, which determine refurbishment, deconstruction or demolition. It is estimated that 70% of the existing stock will be standing in 2050, thus each new building constructed in an energy-wasting manner or retrofitted to a suboptimal level will lock us into a high carbon-footprint future.

3.2. Definition of future-proofed design

Future-proofing is defined as 'designing something that can be resilient to future developments including both mitigation of negative impacts and taking advantage of future opportunities' [20]. This concept is promoted implicitly within the increasingly stringent environmental legislation, building standards and regulations at European and national levels, such as the recast of the European Performance Building Directive and the UK Climate Change Bill [21-22]. When applied to the context of energy and buildings, future-proofing refers to building strategies made at early stages which can be connected to long-term energy solutions, such as ability to accommodate new technologies or space for energy storage, thus achieving optimum energy performance throughout the lifecycle [23].

A future-proofed design strategy entails 'stress-testing' against a range of possible futures to ensure that building decision remain robust of the lifecycle and simultaneously ensuring effective management of future energy requirements. There are two key characteristics that underline this concept:
- The level of uncertainty surrounding the trends and drivers that could influence the energy performance of buildings, which can vary between predictable trends and unknown aspects that cannot be anticipated based on present forecasts.
- The level of availability in product and process innovation; i.e. technical solutions and decision processes to accommodate future aspects of the energy performance.

Future-proofed building strategies should manage both uncertainty and the need for innovation. This will aid the selection of materials, building components and low or zero carbon technologies that will be cost-effective and flexible in accommodating future changes or requirements. The benefits of sustainable building can only be realised over the long-term and, therefore, failure to incorporate futures thinking may result in poor levels of energy performance for decades.

4. Results

A review of policy documents and consultation reports for the identified case studies, along with data gathered via the ongoing survey and interviews, have revealed the extent to which 'best practice' urban settlements accommodate futures thinking in energy-related decisions.

4.1. Trends and drivers affecting the energy performance of urban settlements

Figure 1 reveals that the investigated housing developments acknowledge predominantly four trends and drivers from a broad spectrum of issues affecting buildings by 2050. These include: i) demographic changes due to increase in urban populations and social changes in housing unit and tenure types, ii) the increasingly stringent environmental legislation, building standards and regulations, iii) innovative economic incentives and funding mechanisms for energy efficiency, RET, and community energy networks, and iv) the launch of new technical solutions.

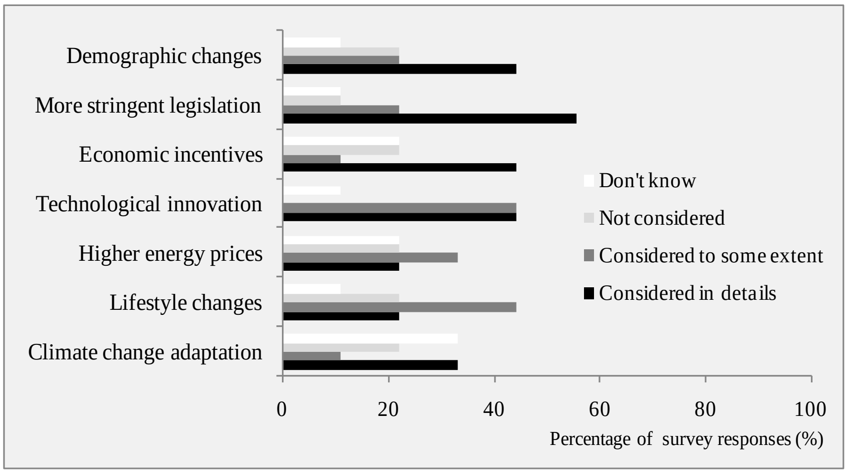

Fig.1. Trends and drivers affecting the energy performance of urban settlements by 2050.

Higher energy prices and lifestyle changes are considered to some extent. The latter refers to the energy-intensive behaviours associated with higher energy consumption, such as the purchase of more appliances, higher preferred lighting levels or room temperatures, and the occupancy of larger living spaces per person. Nonetheless, it is shown that 'best practices' do not fully consider adaptation to a changing climate change, as this trend is not considered or even overlooked in about two thirds of the survey data. Many future impacts of the energy performance of housing developments are already 'locked-in', as result of past GHG emissions. Figure 1 shows that adaptation to a changing climate is not yet a priority at the design stage, as building strategies have mainly focused on mitigation; i.e. reducing GHG emissions via energy efficiency measures and the use of RET.

4.2. Future-proofed building strategies

This section includes a list of building strategies adopted in the selected case studies as shown in Table 2, along with observed limitations and directions for future research. These future-proofed building strategies aim to accommodate the trends and drivers affecting the energy performance of buildings by 2050 (see Figure 1). In addition, Table 2 provides an understanding of the decision-making process behind them. Survey data reveals that the majority of the building strategies are selected due to the commonly used and cost-effective environmental design techniques; i.e. strategies to mitigate GHG emissions with energy efficiency measures.

Table 2: Future-proofed building strategies used in the case studies.

Building strategies	Main reason for selection
Energy efficiency of the building fabric: • Passive systems: location and orientation, natural daylighting, external shading, natural ventilation • Active systems: optimum insulation, thermal mass, and advanced glazing • Low energy lighting • Low energy appliances • Control systems: building management systems and smart metering	Standard practice, cost-effective
Low and zero carbon technologies: • Individual buildings: solar thermal panels, photovoltaic (PV) panels, micro-wind, heat pumps • Local energy networks - Gas-fired and biomass-fuelled Combined Heat and Power (CHP) plants - District heating and/or cooling systems - Large wind turbines outside built-up areas	Demonstration project
Low embodied energy materials and building components	Demonstration project, regulatory requirement
New methods of construction (e.g. prefabricated solutions, green roofs and walls, cool roofs, phase change materials, smart facades)	Demonstration project, regulatory requirement, marketing or 'green' image

Apart from the abovementioned environmental design features, the analysis of the case studies shows that 'best practices' integrate economic aspects of sustainability to enhance long-term affordability in the building layouts, functions, materials, building components and energy systems. This is achieved by process innovation in business models for the commercialisation of new technologies or the establishment of energy partnerships and community trusts. An example can be the establishment of an Energy Service Company (ESCO), which engages in a long-term arrangement with a developer to cover both the financing and management of the energy-related costs over the development's upfront and running costs. Furthermore, 'best practices' demonstrate social aspects of sustainability, by ensuring buildings for all types of occupants with a variety in housing unit and tenure types and by enhancing health and well-being. Social acceptability of low or zero carbon technologies is also achieved via community engagement and public participation.

Nevertheless, Table 2 reveals a lack of adaptation strategies that could bring flexibility into the building design and enhance the ability to undergo the impacts of future changes. The case studies do not fully demonstrate a diversified mix of energy sources and the ability to accommodate future changes or mandatory requirements regarding new technologies, such as PV-ready roofs or space for energy storage. Adaptable building strategies that address socioeconomic issues, such as internal space flexibility to support new behavioural patterns (e.g. home-based working) should also be incorporated in the building design. Another issue that is not considered in detail is a specific strategy for the decommissioning stages at the early lifecycle stages. Demolition should be avoided and designers should opt for materials and building components that can be disassembled for re-use and recycling. Improvements in energy efficiency have led in reduced energy consumption at the operational stage, and therefore the relative significance of embodied energy has increased, as it forms a higher proportion of the total amount of energy used during the lifecycle [24]. The findings, however, reveal that embodied energy is not integrated systematically, as this choice is related to a demonstration project and the establishment of any mandatory or prescriptive requirements for such calculations.

5. Concluding discussion

Future-proofed building strategies aim to ensure the delivery of resilient and flexible buildings that foster low carbon development and have potential for cost savings, lower running costs, and added-value in the future. To date, the case study research demonstrates that a starting point to future-proof a housing development is to be one step ahead of the building regulations with high energy efficiency measures and installation of cost-effective RET. It also highlights the importance of stakeholder engagement and the need for a step change from short-term mindsets to long-term strategic thinking and full lifecycle considerations, since it is the early decisions that determine whether a project will be sustainable and future-oriented or not. Nonetheless, when 'best practices' think about future-proofing, they focus predominantly on mainstream and cost-effective building strategies, such as energy efficiency, low energy lighting, and control systems. More innovative features, such as novel RET, local energy networks, embodied energy considerations, and new methods of construction, are still not mainstream solutions and are mainly considered due to a demonstration character, regulatory requirements, marketing or 'green' image purposes of a project, when testing novel energy solutions.

At present, it is challenging to deal with uncertainty and long-term decision-making on the building design. Interviewees agree that there is still no single, truly holistic sustainability assessment method that can integrate futures thinking into the evaluation of the energy performance, thus bringing flexibility to the building design. The case studies reveal that futures techniques have only been applied to a limited fashion in urban settlements. Futures techniques can help identify both anticipated and uncertain outcomes, bring together different perspectives, challenge current thinking, and aid robust decision-making. They are a family of tools that have not been developed with sustainability in mind but their orientation is of direct relevance to future-proofing. For instance, Scenario Planning is one commonly used technique, which has become increasingly dominant in business strategy and long-term planning of products, processes and industrial sectors [25].

The case studies have revealed the lack of a comprehensive technique to integrate futures thinking into *ex ante* sustainability assessment methods. At present, mainstream techniques and tools, such as Environmental Impact Assessment (EIA) or building rating tools (e.g. BREEAM, Code for Sustainable Homes, LEED, etc.), give emphasis to particular environmental themes rather than social and economic and focus predominantly on predictable energy trends and drivers. Therefore, they tend to overlook reasonably foreseeable or unknown dimensions of the energy outlook. A new generation of decision-support tools should be developed, which will adopt a hybrid approach combining mainstream sustainability assessment methods (e.g. EIA) with futures techniques (e.g. Scenario Planning) for the appraisal of the energy performance of housing developments.

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