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Do the numbers stack up? Lessons from a zero carbon housing estate

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ABSTRACT

Many countries are searching for ways to reduce the energy and carbon impact of housing. The terms net zero-energy home and net zero-carbon home have entered the policy lexicon, without clear definitions and without widespread understanding of the likely policy impact. Is the concept limited to bespoke architect driven buildings for specific green clients, or does it have relevance in the mainstream house building sector and for typical households? When we consider volume house building and contemporary lifestyles, what is the energy end-use reality of so called zero-energy homes? Can government policy instruments deliver housing estates that are thermally comfortable, energy efficient and powered by renewable energy?

The Lochiel Park Green Village in South Australia represents a genuine attempt through government policy processes to create a suburb of (nearly) zero-energy homes in a near zero-carbon estate. The development includes 103 highly energy efficient homes of various sizes, all utilising solar thermal and solar photovoltaic sources, and built to stringent environmental urban design guidelines. The energy used and generated at each house is being monitored and analysed to extend our understanding of what happens when families bring their energy habits to near zero-energy homes. Appliance and equipment audits are conducted to extend our knowledge of the energy services utilised in contemporary digital-age lifestyles.

This paper provides an insight into the quanta of energy using appliances and equipment that fill our homes and satisfy our ever-growing needs. The paper presents key results from the first two years of monitoring for the initial tranche of houses, demonstrating that although significant reductions in operating energy use have been achieved, few households have reached a net zero energy standard. The research highlights the extent to which our choice of energy systems and our individual behaviour affect the total annual energy use. The energy end-use and energy generation results are examined to identify the contribution of near zero-energy homes to the twin policy challenges of anthropogenic climate change and peak power demand. Using empirical evidence from extensive monitoring, this paper throws new light on the energy use of actual families in contemporary near zero-energy homes.

1. Introduction

There is substantial scientific evidence indicating that anthropogenic greenhouse gas emissions, particularly those related to carbon based energy use, has reached a level which is altering the global climate [1,2]. In many nations housing has advanced to the point that households demand high levels of thermal comfort, and require hot water and other services on demand, at the flick of a switch, irrespective of the environmental impact of making the required energy available [3]. Consumer housing expectations and cultural norms, embedded institutional construction practices, regulatory standards and dominant technologies have evolved in parallel without due consideration of the resultant ecological footprint [4]. What we build, and how we use those buildings, is the result of many social, economic and technical influences, such as the cultural institutions that shape communities, the technology norms applied by industry, the education and training of the various actors involved in creating new housing, and the experience of actors who demand and use new residential products [5]. This interaction of actors, institutions, rules and technologies over many years has brought us to the point where housing has a significant negative impact on the local environment and the global climate [6].

Passively designed, highly energy efficient buildings with integrated renewable energy technologies are seen as a key solution to reduce the greenhouse gas emission impact of our residential

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dwellings [7–9]. Available literature suggests green niche developments, created relatively free of the constraints of the dominant incumbent socio-technical regime, may play a role in transitioning that regime to one with housing that has a lower environmental impact [10,11]. There is growing evidence that low-energy niche housing can provide sites of learning and network building, helping to transform technology and policy as well as creating broader demand in the mainstream market [12–14].

Progress towards highly energy efficient appliances and lighting, the application of passive solar design, plus reductions in the cost of solar technologies have combined to encourage building practitioners and researchers to explore the potential to create homes that have little or no impact on net anthropogenic greenhouse gas emissions. Examples of dwellings claiming to be net zero carbon or net zero energy are appearing on several continents [15–20]. The International Energy Agency research group "Towards Net Zero Energy Solar Buildings" has mapped almost 300 net zero energy and energy-plus buildings [19].

The concept is not restricted to individual dwellings. Larger-scale developments have been created which also approach a net zero energy or net zero carbon performance level [21–23]. Niche green developments such as Solarsiedlung Freiburg am Schlierberg in Germany, BedZED in the United Kingdom, and the Currumbin Eco-village in Queensland have allowed private developers to showcase specific visions of larger-scale sustainable residential development. Even city-scale projects are planned to create the equivalent of zero carbon communities, although these developments rely mostly on the application of nearby renewable technologies rather than zero energy or zero carbon homes [24,25].

Common to the zero carbon or zero energy house case studies, and the larger scale housing developments, is the strong vision of an individual architect or developer for a high level of sustainability rather than the collective policy development of multiple government agencies. For example: BedZED was the vision of the social enterprise BioRegional and architect Bill Dunster; the Solarsiedlung Freiburg am Schlierberg was created through the vision of architect Rolf Disch; and the Currumbin Eco-Village was the creation of developer Landmatters Currumbin Valley Property Ltd. Is this solution limited to one off designs by specialist architects for highly green motivated clients, or can this approach be mainstreamed through deliberative government policy to transition the local building industry toward low energy housing estates for the general public?

In Adelaide, South Australia, the state government set out to work with larger volume home builders to create highly energy efficient buildings with solar technologies for the general housing market [26]. The government also decided to monitor the performance of the homes over an extended period to help develop an understanding of the actual performance of near zero energy homes inhabited by a range household types, sizes and life-stages. The government's role in the development of the niche green residential village, combined with the systematic monitoring of the whole estate, provides a unique case study that complements the analysis of private sector fashioned low-energy developments. The Lochiel Park case study demonstrates the result of utilising public policy processes to establish ambitious sustainability targets and minimum construction standards, while leaving the private sector responsible for delivering the housing product through normal competitive housing market processes.

With governments in Europe, North America, Australia and Asia considering raising the regulation of building energy and carbon performance towards a net zero energy or carbon standard [27–30], this case study throws light on the impact government can play in the transition to low carbon housing, and the energy performance of near zero energy homes delivered by such policies.

Starting with some historical background to the creation of Lochiel Park, this paper discusses the monitoring systems incorporated into each home and provides detailed results from a two year period of monitoring. The discussion section analyses how close the first tranche of houses get to the zero energy target, and identifies a number of key energy use influences. Finally the paper concludes by examining the role zero energy homes may play in reducing local network peak electrical power loads, and as a solution to the mitigation of anthropogenic greenhouse gas emissions.

2. The creation of Lochiel Park

Recognising the need to transition the local building sector toward more sustainable practices, the South Australian Government chose to showcase the cutting edge of climate relevant sustainable urban development by creating Lochiel Park, a model green village of national and international significance [31].

Located on 15 ha of surplus government land, approximately 8 km North-East of the Adelaide central business district [32], the development was originally intended to be disposed to the property market as a standard broad-acre land sale of 150 residential allotments. A change of state government introduced new policy objectives, in particular an increased interest in addressing climate change and other environmental issues [26]. This resulted in the newly elected Premier of South Australia declaring in 2004 of the project's new intent [26]:

> "I want South Australia to become a world leader in a new green approach to the way we all live. The Lochiel Park Development will become the nation's model 'Green Village' incorporating Ecologically Sustainable Development (ESD) technologies."

Given explicit direction from the State Premier to develop a niche green urban estate of world standing, an advisory panel of state and local government officials and community representatives was established to define high level objectives across a relatively broad range of areas including environmental sustainability, social sustainability, urban form, transport, industry development and economics [32]. By benchmarking against major international and national niche green residential developments, specific performance targets were set covering potable water, open space, water recycling, energy technologies, revegetation, passive solar design, waste reduction and management, designed building life span, local transport use, community interaction, and many other impacts. These detailed targets were refined in consultation with the various expert groups [26], with final design overarching targets set at a reduction of:

- 66% energy used
- 74% greenhouse gas emissions
- 78% potable water use

Expert consultative groups for energy and water helped translate these targets into building standards and guidance materials that could communicate the desired sustainability principles to be applied to each house. These were published in the Urban Design Guidelines [33], with minimum requirements including:

- 7.5 NatHERS Stars thermal comfort
- Solar water heating, gas boosted
- 1.0 kWp photovoltaic system for each 100 m^2 of habitable floor area
- High energy star rated appliances
- Low energy lighting (CFLs & LEDs)
- Ceiling fans in all bedrooms and living spaces