AUSTRALIAN SUSTAINABLE BUILT ENVIRONMENT COUNCIL

NET ZERO EMISSION HOMES:

An Examination of Leading Practice And Pathways Forward

June 2012

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This report is based on findings from independent research conducted by the Institute for Sustainable Futures, University of Technology, Sydney.

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The member organisations of the ASBEC Zero Emissions Residential Task Group may not necessarily have policy positions on all the measures contained in this report.

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President's Foreword

There is a substantial need to make traditional housing more climate friendly, with low emissions and improved resilience to the impacts of climate change.

The Australian Sustainable Built Environment Council (ASBEC) is the peak body of key organisations committed to a sustainable built environment in Australia.

ASBEC members are industry and professional associations, non-government organisations, tertiary institutions and government observers, who are involved in the planning, design, delivery and operation of our built environment, and are concerned with the sector's social and environmental impacts.

ASBEC's Zero Emissions Residential Task Group comprises representatives from the Green Building Council Australia, Australian Institute of Architects, Australian Conservation Foundation, Association of Building Sustainability Assessors, Building Commission Victoria, Commonwealth Department of Climate Change and Energy Efficiency, NSW Office of Environment and Heritage, City of Melbourne, the Property Council of Australia and Sustainability Victoria.

Globally, buildings account for more than 40 per cent of primary energy use and 24 per cent of greenhouse gas emissions (IEA SHC & ECBCS 2010). In order to deliver a low carbon future, the evolution of residential housing delivery must be considered.

The Institute for Sustainable Futures (ISF) was commissioned to undertake a global snapshot of pathways to delivering zero carbon homes.

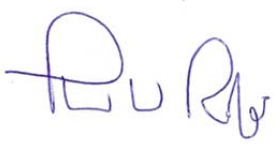
ISF's report assesses leading Australian and international practice in the delivery of zero carbon homes. It seeks to examine the lessons learned from lead practitioners and considers the applicability of international initiatives in the Australian context.

This report specifically focuses on a zero carbon goal while recognising that many of the proposed actions will be equally relevant to low carbon or beyond zero carbon goals. This report should be read together with its sister document released by ASBEC, *Net Zero Emission Homes: An Industry Roadmap*.

This project builds on an earlier project for ASBEC looking at definitions of zero carbon buildings and uses the definitions proposed in that report and complements work undertaken to examine the challenges of retrofitting residential homes.

ASBEC invites comments and feedback from all stakeholders to help forge a strong path towards net zero emissions housing.

If your organisation is interested in supporting the further stages of this innovative work or if you would like more information, please contact the task group chair, Adam Beck, ph. 02 8239 6200 or adam.beck@gbca.org.au or the Executive Officer of ASBEC, Suzanne Toumbourou ph. 02 8252 6707 or eo@asbec.asn.au.



Tom Roper
President, ASBEC

Acknowledgements

ASBEC and the Institute for Sustainable Futures would like to thank the people who contributed to this report by participating in interviews, providing feedback and input, or assisting with the research in other ways. The Residential Development Council of the Property Council of Australia commissioned and guided this work, and we would like to thank Caryn Kakas and Caroline Speed for their excellent contributions.

The Zero Emissions Residential Task Group of the Australian Sustainable Built Environment Council initiated this project. We would like to thank all the members of ASBEC for supporting this project, and particularly Mark Allan (Task Group Chair, representing the Green Building Council of Australia), Jayne Paramor (ASBEC's Executive Officer) and all the Task Group members.

Many people gave up their time to speak with us during the project and provide their insights into zero emission buildings, including Gordon McAllister (Department of Climate Change and Energy Efficiency), David Waldren (Grocon), Adam Selvay (Henley), Chris Barnett (Third Skin), Daniel Smee (Jade Projects), Gary Wright (Right Homes), Lisa Danker (Landcom), Ross Maher (Association of Building Sustainability Assessors), Kristian Hetyey (Burbank), Caroline Pidcock (Pidcock), Peter Cotton (Mirvac), Siobhan Toohill (Stockland), Philip Alviano (Master Builders Association Victoria) and Alex Stravakos (Sustainabylt). We sincerely appreciate their time and their willingness to share their thoughts.

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Executive Summary

Background

On behalf of the Australian Sustainable Built Environment Council's (ASBEC's) Zero Emissions Residential Task Group (ZERTG), the Residential Development Council (RDC) of the Property Council of Australia commissioned the Institute for Sustainable Futures (ISF) to:

- Document and assess leading Australian and international practice in the delivery of zero carbon homes
- Assess the applicability of international initiatives in the Australian context
- Present international and domestic case studies of homes that contribute to the goal of making zero carbon homes mainstream
- Make recommendations on a pathway towards zero carbon homes in Australia by 2020.

This project builds on an earlier project for ASBEC looking at definitions of zero carbon buildings and uses the definitions proposed in that report (Riedy, Lederwasch & Ison, 2011). For some, it is too soon to aim for zero carbon and we should be focusing on low carbon. For others, zero carbon is just a stepping stone to buildings that have a net positive or restorative impact. This report specifically focuses on a zero carbon goal while recognising that many of the proposed actions will be equally relevant to low carbon or beyond zero carbon goals.

We reviewed documents and websites on voluntary Australian and international initiatives to deliver lower carbon homes, and government support for lower carbon homes in the form of policy, regulation, targets, grants and incentives. We also interviewed key stakeholders in Australia and internationally to assess the state of the market for zero carbon homes and identify suitable case studies. These sources were used to compile a preliminary roadmap towards zero carbon homes in Australia by 2020.

Key recommendations

The key recommendations of the report are summarised below:

- Establish a consistent long-term, regulated timeline towards zero carbon with industry-agreed targets
- Develop voluntary standards to drive and reward innovation
- Use a single rating system for home sustainability within the National Construction Code, mandatory disclosure and any voluntary standards that is consistent across jurisdictions and includes comprehensive auditing
- Research on the Australian Zero Emission House found an additional cost of 15% and a payback period of around 11 years, which is too long to be attractive to most consumers. To reduce payback periods, implement mechanisms such as cash rebates for low carbon products and materials, innovative financing mechanisms (such as 'pay as you save' schemes and environmental upgrade agreements) and provision of favourable tax treatment.
- Undertake marketing and education to increase consumer awareness of the benefits of zero carbon homes, for example via a recognisable brand and logo, awards programs and targeted communications
- Ensure that a dedicated organisation (like the Zero Carbon Hub in the UK) takes on the role of providing research, education and capacity building to move towards the zero carbon goals. This could include maintaining a database on cost and performance of zero carbon homes, establishing an industry-endorsed definition and terminology for zero carbon homes and developing technology roadmaps for key zero carbon products and services.

More details are provided in the rest of this Summary and the full report.

Voluntary action for zero carbon homes

There are only a handful of existing voluntary initiatives in Australia that explicitly aim to deliver zero carbon homes. These include the South Australian Land Management Corporation's Zero Carbon Challenge, the Australian Zero Emission House Project and several demonstration homes. Cost data from the demonstration homes indicates that low and zero carbon homes are not yet able to compete beyond the high-end housing market.

There will continue to be a role for progressive builders and developers to push the boundaries of technical feasibility and cost-effectiveness with innovative home projects that demonstrate what is possible.

NatHERS and its associated rating tools are used to assess compliance with the National Construction Code but can also be used voluntarily to assess the heating and cooling performance of existing buildings or to demonstrate performance beyond compliance. The other main voluntary rating programs are Green Star and NABERS. None of these tools explicitly target zero carbon and their voluntary uptake in the residential sector is low.

When mandatory disclosure of energy performance for residential buildings is introduced, householders will start to become more familiar with a particular rating approach at the dwelling level. Ideally, future voluntary rating systems would be able to build on the mandatory system, using similar methods and language. This will be crucial to avoid marketplace confusion, while providing additional incentives to go beyond mere reporting of energy performance.

Before considering international initiatives it is important to understand how comparable the housing markets are in other countries. Canada's housing market is most comparable to Australia's in total size and number of new builds per year, although roughly 50% bigger on both counts. The housing market in the United States is roughly ten times larger than that in Australia but otherwise has a similar structure to Australia with respect to the proportion of new builds each year versus total dwellings. European housing markets are less similar to Australia. For example, in the UK, the number of new homes built each year is not much different to Australia, despite a population that is three times larger.

Leading international voluntary initiatives on zero carbon homes include voluntary energy and carbon standards for single homes (e.g. Passivhaus, MINERGIE, R-2000, Super E, the UK Code for Sustainable Homes and several voluntary standards in the United States) and precinct-scale developments (e.g. Climate Positive and One Planet Living), voluntary targets (e.g. the 2030 Challenge) and coalitions established to facilitate the emergence of zero carbon homes (e.g. the Net Zero Energy Home Coalition in Canada and the World Business Council on Sustainable Development's Energy Efficiency in Buildings project). Canada's Net Zero Energy Home Coalition is of particular interest as a possible model for coordinating voluntary action.

Key lessons from the international initiatives include:

- The need to align voluntary and regulatory schemes (so that they complement and support each other)
- The value of adopting consistent language and assessment methods throughout all initiatives
- The use of voluntary schemes to build initial momentum and incentivise action prior to regulation.

One important point to note is that most of the voluntary initiatives around the world focus primarily on delivering new zero carbon homes, rather than retrofitting existing homes to achieve a zero carbon standard.

Government support for zero carbon homes

Australian policy and regulation for the building sector is constantly changing. The National Construction Code regulates the residential building sector and the National Strategy for Energy Efficiency is driving the development of several new policy initiatives, including the preparation of a National Building Energy Standard-Setting Assessment and Rating Framework and the proposed mandatory disclosure of home energy performance from 2012.

However, until the release of the Framework, which has been delayed, the future structure of building sector regulation remains uncertain. It is not yet clear whether the Framework will establish long-term energy and greenhouse targets for buildings, or will merely establish a timeframe for review of standards over the coming decade.

The feasibility of reaching zero carbon for all new homes by 2020 remains uncertain. The UK is aiming for 2016 and the government released its first proposals on this target in 2006. A recent review of progress towards a series of timelines to support the delivery of the 2016 target identifies that whilst 'some progress' has been made 'urgent action' is now required to achieve the ambitious goals (Zero Carbon Hub, 2011b). California is aiming for 2020 and released its plan in 2008. A California Energy Efficiency Progress Report identifies that whilst there have been some significant successes, including the growing number of California's zero net energy buildings each year, there is a 'real risk' that the Strategic Plan goals will not be reached (California Energy Division, 2011). The Canadian Implementation Plan released in 2011 is targeting 2030.

Based on this international experience and the difficulties other nations are finding in meeting their stated targets, it could be argued that Australia has left it a bit late to start planning towards a 2020 target. Further, some of our interview participants spoke of fierce industry resistance to a zero carbon pathway and a lack of political will to go down that path. A 2025 zero carbon target, with interim targets in 2015 and 2020 implemented through tightening of the BCA requirements, may be a more feasible pathway given that there is still substantial work to do on developing a suitable rating tool. Although it is worth noting that, given the speed to market and success of the Green Building Council of Australia's (GBCA's) suite of Green Star tools, a new residential rating tool could be developed, tested and implemented quickly.

There are industry concerns about the quality, coverage and auditing of current rating tools used to assess compliance with BCA requirements and the corresponding state regulations. Significant regulatory differences between States also increase compliance costs and the potential for market confusion. The National Building Framework considers the possibility of moving away from NatHERS to a broader rating tool; many interviewees noted the value of doing so. The current consultation on mandatory disclosure of energy performance for homes represents an opportunity to develop and implement a new rating tool covering a greater proportion of operational energy use, to establish reliable compliance and auditing mechanisms and to move towards nationally consistent energy efficiency requirements for buildings. It is vitally important to take up this opportunity, as the rating approach specified for mandatory disclosure is likely to be locked in for quite some time. There is also no guarantee at present that the states and territories will adopt a consistent approach to mandatory disclosure, which would further increase compliance costs and marketplace confusion.

The Australian Government Clean Energy Future package includes initiatives that will specifically support industry skills and retrofitting of existing homes to improve their energy and carbon performance. There is potential to influence the delivery of these initiatives so that they contribute towards the emergence of zero carbon homes and help to build the skills needed to deliver such homes.

Leading international regulatory initiatives include the European Directive on Energy Performance of Buildings (requiring "nearly zero energy" homes by 2020), the United Kingdom's plan to require all new homes to be zero carbon by 2016, California's Long-Term Energy Efficiency Strategic Plan (which has a goal for all new residential buildings to be zero net energy by 2020) and Canada's new provisions in the National Building Code and National Energy Code for Buildings to require energy efficient houses.

Although the regulatory context in these jurisdictions is not directly comparable to Australia, there are some valuable strategic lessons about how to implement regulation of zero carbon homes.

First, it is critical to establish a consistent, long-term timeline and targets for increasing building energy performance standards to provide industry certainty and drive innovation. Second, there are substantial barriers to overcome in moving towards zero carbon homes and there is value in having a dedicated organisation to undertake research, education and industry capacity building to overcome these barriers. The

UK Zero Carbon Hub, chaired by Paul King (CEO of the UK Green Building Council), provides an excellent model that could be emulated in Australia with support from the Green Building Council of Australia. Third, the most successful international approaches use consistent mandatory and voluntary standards based on the same rating systems. Governments, for example in Canada and the United Kingdom, have provided the coordination to ensure alignment of voluntary and mandatory standards. Australia has several different rating tools that measure different aspects of residential building performance and would be better served by establishing a single national rating tool that provides a broad measure of operational energy and carbon performance. It is the role of government to provide the necessary coordination and set long-term regulatory objectives, whereas industry may be best placed to deliver the actual rating tools, for example through the GBCA.

The market for zero carbon homes in Australia

Consumer demand for low and zero carbon homes in Australia is low. Most low and zero carbon homes are either demonstration homes or are delivered for high-end consumers of bespoke homes. Some of our interviewees reported increased demand for low or zero carbon homes, mainly driven by rising electricity prices but the mainstream mass housing market is still delivering to minimum energy performance standards.

There are several reasons for the low demand. First and foremost, low and zero carbon homes are not yet seen as good value for money in most markets. Data on the additional cost to deliver a zero carbon home is highly variable in different markets but experience from the Australian Zero Emission House found an additional cost of 15% and a payback period of around 11 years. Few homebuyers are willing to accept a payback of more than 5 years and there are few innovative financing mechanisms at present to overcome the barrier of the initial capital cost. Despite this, cost trends for zero carbon homes are in the right direction, given that energy prices are rising and costs of renewable energy technologies are falling. Second, consumer awareness of the benefits of low and zero carbon homes appears to be low. While some developers promote these homes, most do not. Increased awareness of energy costs and the comfort and lifestyle benefits of zero carbon homes are crucial. Third, the building industry lacks the skills to deliver low and zero carbon homes at scale for mainstream new housing supply.

A roadmap for zero carbon homes in Australia

A comprehensive roadmap for zero carbon homes in Australia is beyond the scope of this report. However, ISF has identified key strategies and opportunities that ASBEC could pursue to facilitate the emergence of zero carbon homes by 2020. Strategies are grouped into the following categories:

- Advocacy
- Building industry skills and capability
- Financing and cost-effectiveness
- Supporting voluntary action
- Marketing
- Research and technical support
- Alliances and collaboration.

Advocacy

While some of our interview participants expressed a preference for voluntary initiatives over regulation, others saw a role for regulation in delivering zero carbon homes and some saw it as critical.

Recommended strategies could include:

- Support mandatory disclosure of energy and greenhouse performance but advocate for a more complete rating of sustainability performance and for national consistency in implementation
- Seek industry and government support for development of a new national home sustainability rating tool. The rating tool should provide a single, consistent approach for use in mandatory disclosure and

assessment of performance against BCA requirements and voluntary standards. The rating tool should include a full set of ratings at release that covers the various zero carbon definitions (i.e. base building, occupied, life cycle etc.) and positive energy homes. While the rating tool may be based on modelled performance, it should be supported by a comprehensive performance-monitoring program to identify ongoing opportunities for improvement in the models and in practices. The tool should cover energy, greenhouse and water performance, allowing a broader strategic approach focusing on zero impact homes, rather than just zero carbon homes.

- Advocate for a comprehensive training, certification and compliance auditing program to support the new rating tool. Auditing of homes to check whether they are constructed to the standard they were modelled at under NatHERS is limited at present and interviewees indicated that many homes would not achieve the modelled energy performance in practice. Whether or not there is a new rating tool, an audit program is essential. In addition to audits, the compliance program could include innovative on-the-job and industry-relevant training approaches, with an educational and motivational purpose rather than a compliance purpose. Avenues are also needed for auditors and industry to provide feedback on how rating schemes are operating in practice.
- Set an industry agreed target for inclusion in the National Buildings Framework. For example, a target for all new homes to be zero carbon by 2025 with interim targets for 2015 and 2020 and additional targets for home renovations. COAG is likely to make a decision on such targets in the first half of 2012, so there is still an opportunity for ASBEC to influence the decision. Establishment of a long-term regulatory target can provide the building industry with greater certainty and support innovation to reduce the cost of delivering zero carbon homes. Targets should be implemented through amendments to the Building Code of Australia (for thermal performance and fixed appliances), with additional policies and incentives to move towards zero carbon for plug in appliances.
- Plan ongoing work programs to take advantage of review points established in the National Buildings Framework, once it is released.
- Strengthen requirements in the BCA relating to building sealing to reduce air infiltration and leakage
- Advocate for nationally consistent implementation of energy and carbon targets established in the BCA (i.e. harmonise requirements across jurisdictions)
- Support the development of a National Energy Savings Initiative (ESI) and advocate for it to include specific measures to support emergence of zero carbon homes, such as generation of bonus energy efficiency certificates for homes that achieve a verified zero carbon standard (based on monitoring of actual performance)
- Ensure funding for the Low Income Energy Efficiency Program (LIEEP) under the Clean Energy Future Package is allocated to delivery of zero carbon homes. An application could also be made for funding under the Household Energy and Financial Sustainability Scheme.
- Improve lot layout and solar access rules to support good passive solar house design. There is a measure in the NSEE on this but our interview participants argue more needs to be done in this area.

Building industry skills and capability

- Develop a zero carbon home web portal, or build on existing websites such as Your Home and Living Greener, with information for builders and consumers on zero carbon homes, including definitions, the benefits of zero carbon homes and a database of useful building products, techniques and suppliers for building zero carbon homes in various climate zones. An accreditation process or other quality assurance process may be valuable to create and maintain confidence in the products and services promoted on the site.
- Collect Australian case studies of zero carbon homes in different climate zones and markets and publicise through the web portal. The case studies will have the twin benefit of providing information to the industry on how to achieve zero carbon homes and promoting and supporting early movers.

- Work with organisations such as the Department of Education, Employment and Workplace Relations, Skills Australia and the Construction and Property Services Industry Skills Council to ensure that skills, education and training initiatives like the Clean Energy and Other Skills Package meet the needs of the building industry. For example, innovative on-site training programs that teach energy efficiency skills on the job may have greater impact for builders than classroom training. Training programs need to cover the full range of professions involved in delivery of homes, including planners, designers, builders and building-related trades.
- Seek funding from the National Workforce Development Fund to develop and deliver specific building industry skills training on energy efficiency and zero carbon homes
- Assist with the development of new training and accreditation programs for building assessors to support the introduction of a new national home sustainability rating tool and new mandatory and voluntary standards.
- Establish an annual awards program or competition to recognise projects or organisations that lead the way in delivering cost-effective zero carbon homes
- Support the collection of data needed for strategic urban redevelopment, including data on property, planning, infrastructure and demographics, which needs to be brought together into shared urban spatial information systems to enable exploration of development opportunities and regeneration sites by property developers, design and construction professionals, investment organisations, local government bodies and neighbourhood communities. (In 2011, projects to develop information platforms began at the Australian Urban Research Information Network (AURIN) and the CRC for Spatial Information (Newton, Murray, Wakefield, Murphy, et al., 2011)).

Financing and cost-effectiveness

- Develop and regularly update the business case for zero carbon homes. (Interview participants indicated that governments will not move to require zero carbon homes unless cost-benefit analysis indicates that there is a community benefit in doing so).
- Prioritise actions to achieve low and zero carbon homes in a way that reduces costs over the long term through incremental changes to National Construction Code. Requiring homes to maximise passive solar design first will reduce the need for specialised building products and will minimise costs down the track to improve the performance of the home.
- Provide cash rebates to builders for use of selected low carbon building materials and products, such as double-glazing, insulation or low-e glass, that have the potential for a large mainstream impact. Initial rebates can help to drive demand, build economies of scale and drive down costs over time. Mechanisms to explore how these discounts could be passed on to consumers should be considered.
- Work with financial institutions to develop innovative financing mechanisms to ease the up-front cost of energy efficiency and renewable energy improvements. For example, Pay As You Save schemes provide loans for carbon reduction measures that remove the upfront cost. Repayments are made from energy bill savings and arrangements can be made to link the loan to the home so that occupants do not keep paying once they move out. Governments may also provide support to offer the loans at reduced interest rates. (Efforts will need to be made to gain consumer confidence in such programs given the failings of the past Green Loans and home insulation programs).
- Support the development of environmental upgrade agreements as a way of financing retrofits of existing multi-residential buildings. These schemes have already been introduced in NSW and the City of Melbourne (as part of the 1,200 Buildings Program). They allow for the cost of retrofits to be recouped through increases in Council rates, which avoids the split incentive that exists in rental properties.
- Advocate for fast track planning processes, conditional on achieving zero carbon housing on that land.

- Advocate for favourable tax treatment for zero carbon homes, such as stamp duty concessions for zero carbon homes and tax deductions for renovations that achieve particular energy efficiency standards.

Support for voluntary action

Canada and the UK are among the leaders in delivery of zero carbon homes, and both countries use a mix of voluntary and mandatory standards to encourage the emergence of such homes. Voluntary standards clearly have a role to play in rewarding market leaders and building consumer awareness of low and zero carbon options. However, it is critical that voluntary standards are aligned with mandatory requirements and market feasibility.

We recommend that ASBEC agree to a voluntary standard for zero carbon homes ahead of a mandatory standard. The ideal is to work towards a voluntary standard that will use the same assessment system used for mandatory disclosure of sustainability performance and for assessment of compliance with the BCA. Voluntary standards recognise performance at the high end of the rating scale, inspiring developers and builders to go beyond minimum regulated performance. This supports sustainability champions and publicises their experience as a resource for other builders.

The voluntary standard should include a certification process, regular audits of compliance and a suitable logo that certified homes can display to build consumer awareness and recognition.

Marketing

As cost-effectiveness begins to improve, marketing zero carbon homes will become increasingly important. The following initiatives are recommended:

- Consolidate existing market research on consumer demand for low and zero carbon homes
- Conduct new research to develop a more comprehensive picture of the barriers to consumer acceptance of zero carbon homes in different markets. (This research may allow identification of niches where zero carbon homes are closest to widespread acceptance, opening up opportunities to develop technologies and practices in those niches before mainstream adoption).
- Support initiatives that give consumers better feedback on their electricity use, such as smart metering with real-time feedback and energy bill benchmarking
- Develop consumer-focused materials on the benefits of zero carbon homes. Emphasise financial benefits (in the context of rising energy prices) and provide evidence for comfort benefits, health benefits and increases in standard of living in these and other marketing materials.
- Support the development of user manuals and home orientation training for new occupants of zero carbon homes so that consumers learn to maximise the benefits of these homes
- Work with media partners to provide consumers with simple information, ideas and plans for building or renovating zero carbon homes
- Maximise media exposure for other initiatives discussed above, such as the awards program for leading zero carbon homes
- Ensure that the voluntary standard discussed above establishes a recognisable brand and logo that will become familiar over time
- Build on existing open house day programs, such as Sustainable House Day
- Provide information to consumers on what it would take to increase the energy efficiency performance of their house, e.g. provide a report with recommendations for achieving higher levels.
- Give consumers information that is easy to understand quickly and that has value to them, e.g., \$savings/m^2 or per home
- Ensure effective recognition of people and organisations that deliver zero carbon products and services and create brand champions

- Facilitate public awareness of passive solar, building methods
- Support efficient operation of low and zero carbon homes.

Research and technical support

Many of the initiatives identified here will require ongoing research and technical support. The Zero Carbon Hub in the UK is a useful model for provision of ongoing research and technical support to overcome barriers to zero carbon homes. Some research initiatives have already been mentioned above. Additional recommended initiatives include:

- Build a database on energy and carbon performance of zero carbon homes and the additional costs to achieve that performance
- Support research comparing as-built energy performance to rated energy performance. This will help to identify opportunities to improve both rating tools and building practices. There may be opportunities to collaborate with the Commonwealth Government's existing Energy Efficiency Data Project.
- Develop an industry-endorsed definition of zero carbon homes, building on the work already undertaken on definitions (Riedy, Lederwasch & Ison, 2011)
- Collaborate with the CSIRO, or other interested organisations, on development of a home design tool for zero carbon homes that will help builders and consumers to make decisions about the most cost-effective features to include in a design to achieve zero emissions
- Develop a technology roadmap to support the development of technologies that are critical to the mainstream delivery of zero carbon homes
- Support occasional research on technical issues where these are critical to the further development of zero carbon homes, such as alternative construction techniques like reverse brick veneer or automation methods to reduce reliance on occupant behaviour.
- Support research into how to enable the electricity grid to handle increasingly decentralised and time-variable electricity generation from buildings.
- Support research into the technologies and practices available to achieve zero carbon standards in multi-residential buildings and in renovations of existing buildings, as these areas are falling behind new detached homes in delivery of zero carbon homes.

Alliances and collaboration

Almost all of the initiatives recommended above require a collaborative approach and financial support. ASBEC should seek to collaborate with organisations outside its current membership, potentially take on a facilitation role or alternatively strategically partner with other organisations as needed for particular projects.

As noted earlier, the Canadian Zero Energy Home Coalition and its recent Implementation Plan provides a great example of what is needed here. ASBEC is well placed to take a similar role to the Canadian Zero Energy Home Coalition. In highlighting the importance of collaboration the Implementation Plan identifies that:

There are many players that are part of building a Net-Zero Energy Home (NZEH). There are the architects and engineers, the industry professionals who assist with the modelling/simulation optimization and performance testing, the product manufacturers and suppliers, the trades, the developers, the municipalities, the utilities, the industry associations, academia, the R&D networks, the realtors, and of course, there are the builders. And perhaps most importantly, there are the home buyers. In order to ensure that more NZEHs are built, all stakeholders must be engaged (Winkelmann 2011, p.4).

GLOSSARY

ABCB	Australian Building Codes Board
ABS	Australian Bureau of Statistics
ASBEC	Australian Sustainable Built Environment Council
BASIX	Building Sustainability Index
BCA	Building Code of Australia
BTP	US Building Technologies Program
CCBFC	Canadian Commission on Building and Fire Codes
CCTP	U.S. Climate Change Technology Program
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industry Research Organisation
DER	Dwelling emission rate
DOE	US Department of Energy
E-Scale	US EnergySmart Home Scale
E3	Equipment Energy Efficiency Program
EEB	Energy Efficiency in Buildings Project (WBCSD)
EERE	Office of Energy Efficiency and Renewable Energy
ESI	Energy Saving Initiative
ETS	Emission Trading Scheme
ERLs	Energy rating labels
GBCA	Green Building Council of Australia
HEFS	Household Energy and Financial Sustainability Scheme
HERS	Home Energy Rating System
ICC	International Code Council
IECC	International Energy Conservation Code
ISF	Institute for Sustainable Futures
LIEEP	Low Income Energy Efficiency Program
LCC	Low Carbon Communities
MEPS	Minimum Energy Performance Standards
NABERS	National Australian Built Environment Rating System
NatHERS	Nationwide House Energy Rating Scheme
National Building Framework	The National Building Energy Standard-Setting, Assessment and Rating Framework
NILS	No Interest Loans Scheme
NCC	National Construction Code
NCOS	National Carbon Offset Standard
NFEE	National Framework for Energy Efficiency

GLOSSARY

NSEE	National Strategy on Energy Efficiency
NZEH	Net zero energy home
NZR	Net zero ready
PHPP	Passive house planning package
PV	Photovoltaic
R&D	Research and development
RDC	Residential Development Council
RIS	Regulatory impact statement
RTO	Registered Training Organisation
SMEs	Small to medium enterprises
TER	Target emission rate
The Code	The UK Government's Code for Sustainable Homes
VET	Vocational Education and Training
WBCSD	World Business Council for Sustainable Development
ZERTG	Zero Emissions Residential Task Group

1 INTRODUCTION

1.1 Background

The Residential Development Council (RDC) of the Property Council of Australia commissioned the Institute for Sustainable Futures (ISF) to review leading practice examples for setting and achieving targets for zero carbon homes. The RDC commissioned the work on behalf of the Australian Sustainable Built Environment Council's (ASBEC's) Zero Emissions Residential Task Group (ZERTG).

ZERTG is working to develop and promote a framework for the delivery of zero carbon homes. Members of ZERTG include representatives from the Green Building Council Australia, Australian Institute of Architects, Australian Conservation Foundation, Property Council of Australia, the Victorian Building Commission, Sustainability Victoria, Consult Australia, the Department of Climate Change and Energy Efficiency and the City of Melbourne.

A specific team under ZERTG, led by the RDC, is investigating balanced regulation for achieving:

- Zero carbon for new homes by 2020
- Towards zero carbon for existing homes by 2020.

The objectives of this report are to:

- Document and assess the diverse voluntary and government initiatives to support a transition to zero carbon homes
- Assess the applicability of these initiatives in the Australian context
- Present international and domestic case studies of homes that contribute to the goal of making zero carbon homes mainstream
- Make recommendations on a pathway towards zero carbon homes in Australia.

For some, it is too soon to aim for zero carbon and we should be focusing on low carbon. For others, zero carbon is just a stepping stone to buildings that have a net positive or restorative impact. This report specifically focuses on a zero carbon goal while recognising that many of the proposed actions will be equally relevant to low carbon or beyond zero carbon goals.

1.2 SCOPE OF WORK

The scope of work for the project is confined to residential buildings. For the purpose of this project, residential buildings include detached and semi-detached houses (Class 1a), apartments (Class 2) and aged-care accommodation (Class 9c) as defined in the Building Code of Australia (BCA).

This project uses the definition of a zero carbon building proposed by Riedy, Lederwasch & Ison (2011)[1]. That is:

A zero carbon building is one that has no net annual Scope 1 and 2 emissions from operation of building-incorporated services.

- Building-incorporated services include all energy demands or sources that are part of the building fabric at the time of delivery, such as the thermal envelope (and associated heating and cooling demand), water heater, built-in cooking appliances, fixed lighting, shared infrastructure and installed renewable energy generation

[1] The Institute for Sustainable Futures prepared this report for the Australian Sustainable Built Environment Council and it is available from http://www.asbec.asn.au/files/ASBEC_Zero_Carbon_Definitions_Final_Report_Release_Version_15112011_0.pdf.

- Zero carbon buildings must meet specified standards for energy efficiency and on-site generation
- Compliance is based on modelling or monitoring of greenhouse gas emissions in kg CO2-e/m2/yr.

However, the project also considers options to deliver homes that comply with broader definitions of zero carbon buildings, which are also outlined in Riedy, Lederwasch & Ison (2011).

1.3 APPROACH

Our approach comprised the following steps:

- A literature review on current Australian regulatory and voluntary initiatives relating to energy efficiency or greenhouse gas emissions from buildings
- A literature review on international leading practice in delivery of low or zero carbon homes
- Identification of potential case studies of zero carbon homes in Australia and internationally
- Interviews with stakeholders involved in the delivery of low or zero carbon homes
- Analysis of options for transitioning to zero carbon homes and development of recommendations.

Key literature is referenced throughout this report and a bibliography is provided in Section **Error! Reference source not found.**. Stakeholders interviewed during the project are listed in the Acknowledgements at the front of the report.

1.4 Report Structure

The report is structured as follows:

- Section 0 considers the role of voluntary action in facilitating the delivery of zero carbon homes
- Section 3 considers the role of government policy, regulation and incentives in supporting the emergence of zero carbon homes
- Section 4 considers the market for zero carbon homes and options for community education and marketing
- Section 5 proposes elements of a roadmap for zero carbon homes in Australia
- Section **Error! Reference source not found.** lists literature cited in this report.

Case studies of zero carbon or near zero carbon homes are distributed throughout the report to illustrate key points.

2 VOLUNTARY ACTION FOR ZERO CARBON HOMES

This section examines the role of voluntary action in delivering zero carbon homes. Section 2.1 outlines existing Australian voluntary initiatives that support zero carbon homes, Section 2.2 identifies leading international initiatives and Section 2.2.13 discusses options for further voluntary action in Australia.

2.1 Australian Voluntary Initiatives

There are a handful of existing voluntary initiatives in Australia that explicitly aim to deliver zero carbon homes. These include the South Australian Land Management Corporation's Zero Carbon Challenge and the Australian Zero Emission House Project. There are also several voluntary home rating programs, including Green Star and NABERS, that encourage reductions in greenhouse gas (GHG) emissions from homes, without explicitly aiming for zero carbon. The Nationwide House Energy Rating Scheme (NatHERS) and associated rating tools can be used voluntarily, in addition to being used for assessing regulatory compliance. These voluntary initiatives are discussed below.

There are many other demonstration homes that have voluntarily aimed for low or zero carbon, including five homes delivered under VicUrban's Habitat21 project, Mirvac's Harmony 9 sustainable prototype home, Jade Projects' Jade 909 and Landcom's The Ponds. Case studies of some of these are provided elsewhere in the report but space does not permit detailed discussion of all projects nor is it an exhaustive list of current Australian demonstration projects.

2.1.1 The Australian Zero Emission House Project

The Australian Zero Emission House project (http://www.auszeh.org.au/) is part of the CSIRO Energy Transformed Flagship's Low Emission Distributed Energy research program. CSIRO leads a consortium that includes Sustainability Victoria, Delfin Lend Lease, Henley Property Group and Victorian Department of Human Services. The objective of the project is to design and build zero carbon demonstration homes.

To date, three homes have been built or are under construction:

- A demonstration house at Laurimar Estate, Doreen (which is an outer northern suburb of Melbourne). This 4-bedroom detached home uses a combination of efficient design and building practices, on-site renewable energy supply, an advanced energy monitoring and management system and carbon offsets to achieve zero carbon for the full building life-cycle. The home achieves 8 stars in the Nationwide House Energy Rating Scheme (NatHERS) and has a 6kW solar photovoltaic (PV) array. The home was monitored for a year to assess its energy performance.
- A retrofit and refurbishment project at Pascoe Vale in Melbourne. A 3-bedroom detached home, with a NatHERS rating of 2.3 stars was renovated to achieve a 5-star standard by upgrading ceiling insulation, installing wall and subfloor insulation, replacing existing windows with double glazed windows, weather sealing the house and installing energy efficient lighting and appliances.
- Selandra Community Place is a NatHERS 8-star zero carbon home designed as a behaviour changing display home. It is being built at Stockland's Selandra Rise development in Melbourne's outer east and will be used as a meeting space and display centre to help visitors learn about sustainable living.

In response to these demonstration homes, Henley has only had two orders for zero energy homes, which equates to about 0.1% of the total volume built (Henley, pers. comm., 5 March 2012).

In addition to these display homes, the Australian Zero Emission House project is developing:

- A house design tool to help identify the best actions to take to achieve zero carbon in particular homes
- A Housing Stock Option Tool to help governments assess the impact of options for improving the energy efficiency and reducing GHG emissions of housing stock.

Case Study: AusZEH Zero Emission Home (http://www.auszeh.org.au/)

Location:	Doreen, Melbourne	Type:	4 bedroom detached house
Builder:	Henley	Size:	241.5m^2

The AusZEH Zero Emission Home was a collaboration between Henley (the builder), Delfin Lend Lease (the land provider) and CSIRO (research and energy monitoring). The all-electric home is a standard house from Henley's existing catalogue that has been modified to improve its energy efficiency, using readily available processes and materials. The main features include:

- Good design orientation and shading
- Brick veneer construction and insulated waffle pod slab
- Roof and wall insulation
- Double glazing for all windows and sliding doors
- Advanced home sealing to significantly reduce air leakage throughout the home, from a typical 15-20 air changes per hour to less than 4 air changes per hour
- Flat plate, electric-boosted solar hot water system
- Zoned inverter ducted heating and cooling system
- Energy efficient compact fluorescent lighting and appliances (e.g. LED TVs)
- Smart household energy management system, displaying energy performance and allowing easy control of HVAC, standby power and lighting (including remotely)
- 6-kilowatt solar energy generation system
- Electric vehicle charging facilities.

The home achieved an 8-star NatHERS rating. With the addition of the efficient appliances and the solar energy generation system, the home is designed to be a zero carbon occupied home. In addition, offsets were purchased to cover the embodied emissions in the home. An "average family" has occupied the home since December 2010 and actual energy performance is being monitored. It is too early to say whether the home achieves zero carbon in practice.

The base price for the standard house on which AusZEH was modeled is about $260,000. Henley estimates that achieving an 8-star NatHERS rating increased the cost to about $285,000 (a 10% increase) and achieving a zero carbon home increased the cost to $310,000 (a 19% increase). Modelling by Henley indicates that it would take about 9 years to break even on the extra investment for an 8-star home and 11 years for a zero carbon home.

2.1.2 *Zero Carbon Challenge*

The Land Management Corporation (LMC, South Australia), in partnership with the Integrated Design Commission (IDC), established the Zero Carbon Challenge (http://www.lmc.sa.gov.au/zerocarbonchallenge) to

challenge the development industry to aim for zero carbon. The Zero Carbon Challenge is a competition, where interested teams are invited to submit an expression of interest to design a 3-bedroom home to have minimal impact from embodied and operating energy over the 50-year life of the building. Each team must include an architect, engineer and student.

From the expressions of interest, up to five teams will be selected to take the project to full design and documentation stage. They will each receive $10,000 to cover their costs. The winning team will have the opportunity to construct their zero carbon home in the Lochiel Park estate in Adelaide in 2012.

The Zero Carbon Challenge intends to go beyond the standard definition of a zero carbon home used in this report by also offsetting embodied emissions and aiming for zero carbon over a 50-year life cycle. Where carbon offsets are used, they will need to comply with the National Carbon Offset Standard (DCCEE, 2009). LMC will pay for carbon offsets.

The objective of the Zero Carbon Challenge is to demonstrate that zero carbon homes can be delivered at an affordable price and to deliver a model that can be rolled out to the mainstream. Industry training and education is planned along the way to try and build familiarity with this type of building and to show that moving to zero carbon is not particularly onerous (Craig Daniel, pers. comm., 9 June 2011).

Initiatives like this are valuable for building industry and marketplace familiarity with zero carbon homes and demonstrating what is possible. It remains to be seen whether this project will lead to a model that can achieve mainstream acceptance and is economically feasible.

2.1.3 *NatHERS and associated rating tools*

The Nationwide House Energy Rating Scheme (NatHERS, http://www.nathers.gov.au/) is a rating framework that accredits rating tools to assess the thermal performance of homes. Currently, four software tools are accredited for use under NatHERS: AccuRate and AccuRate Sustainability (both developed by CSIRO), BERS Professional and FirstRate 5. Under NatHERS, the rating tools are only required to assess the thermal performance of the home. The assessment is based on modelled performance and uses a star rating, with a maximum of 10 stars. Zero stars means the building shell does practically nothing to reduce the discomfort of hot or cold weather, five stars indicates good, but not outstanding, thermal performance, while ten star homes are unlikely to need any artificial heating or cooling.

The metric used in NatHERS is the energy consumption per unit area in MJ/m^2. In theory, a ten star home does not require any artificial heating or cooling. However, there is still some energy load in some climate zones due to the latent head load in the air (i.e. humidity). Humid areas require extra energy to deal with this heat load.

Most rating tools used under NatHERS only provide a partial assessment of building energy performance. However, the CSIRO has developed a new version of AccuRate, called AccuRate Sustainability, which is approved for use under NatHERS and the National Construction Code (see Section 3.1.3). AccuRate Sustainability provides assessments of hot water energy use, lighting and water use, in addition to thermal performance. This allows building raters to voluntarily provide a more comprehensive picture of home energy performance to clients.

The National Construction Code establishes minimum NatHERS ratings for new homes. From May 2011, the National Construction Code requires that new buildings achieve a six star NatHERS rating. See Section 3.1.3 for further discussion. NatHERS rating tools can also be used voluntarily, for example to assess thermal performance of existing buildings.

2.1.4 *Green Star*

Green Star is a suite of voluntary building rating tools provided by the Green Building Council Australia (GBCA) (http://www.gbca.org.au/green-star/). The tools cover diverse building types and include tools for assessing buildings at the design and as-built stages, with tools for assessing actual building performance currently under

development.

The GBCA does not offer a specific tool for residential homes. For delivery of zero carbon homes, the most relevant rating tools are:

- The existing Green Star Multi Unit Residential tool
- The Green Star Communities tool that is under development.

The first rates entire multi-unit residential buildings and the second will rate sustainability of communities, which might be precinct or neighbourhood scale mixed developments.

2.1.5 NABERS

The National Australian Built Environment Rating System (NABERS, http://www.nabers.com.au/) assesses the performance of existing buildings based on monitoring of their actual energy use. NABERS includes tools for offices, homes, hotels, retail properties, schools, hospitals and transport. The NABERS rating tool for homes allows home occupants to find out how energy and water efficient their home is compared to others and explore simple ways to reduce energy and water bills. Ratings are not available for apartments, units or flats.

To get a rating, a household needs to provide basic household information and energy and water bills for the past 12 months. NABERS is a comparative tool that sets a benchmark of 'current average' performance (2.5 stars) and awards star ratings based on how a building performs relative to this benchmark. Up to 5 stars are available at this time. Importantly, a 5 star building does not equate to a 100% reduction in energy use or emissions.

2.2 Leading international Practice

This section discusses some of the leading voluntary initiatives from around the world that facilitate low or zero carbon homes. This is by no means an exhaustive summary of voluntary initiatives but outlines some of the more prominent and representative initiatives.

Before considering international initiatives it is important to consider how comparable the housing markets are in other countries. Canada's housing market is most comparable to Australia's in total size and number of new builds per year, although roughly 50% bigger on both counts. Although the climate is much colder, Canadian initiatives are the most likely to be applicable in Australia due to the similar volume and structure of the housing market.

The housing market in the United States is roughly ten times larger than that in Australia but otherwise has a similar structure to Australia with respect to the proportion of new builds each year versus total dwellings. Despite the similar structure, the large volume makes technologies and practices viable in the United States that might not be viable in Australia, due to economies of scale. Nevertheless, US initiatives should be relatively applicable in Australia if they do not rely on the greater volume in the housing market.

European housing markets are less similar to Australia than the North American countries. For example, in the UK, the number of new homes built each year is not much different to Australia, despite a population that is three times larger. Renovating existing housing stock is a much more important part of the market in Europe. This does not mean that approaches adopted in Europe are not relevant in Australia, but the different dynamics do need to be taken into account.

The initiatives discussed below include voluntary rating tools (e.g. Energuide in Canada and the Home Energy Rating System Index in the US), voluntary energy and carbon standards for single homes (e.g. Passivhaus, MINERGIE, R-2000, Super E, the UK Code for Sustainable Homes and various US voluntary standards) and precinct-scale developments (e.g. Climate Positive and One Planet Living), voluntary targets (e.g. the 2030 Challenge) and coalitions established to facilitate the emergence of zero carbon homes (e.g. the Net Zero Energy Home Coalition in Canada and the World Business Council on Sustainable Development's Energy Efficiency in Buildings Project).

2.2.1 Energuide Rating System

The voluntary EnerGuide Rating System (http://oee.nrcan.gc.ca/energuide/home.cfm) is a Government of Canada initiative that rates the energy consumption and efficiency of household appliances, heating and cooling equipment, ventilation equipment, new houses and personal vehicles. The rating system shows the home's present level of energy efficiency and the level it could achieve with recommended upgrades. The government encourages homeowners and industry to use the rating system to identify potential ways to decrease the energy consumption of homes. Points are awarded for a range of factors, whereby 100 is the maximum amount that can be achieved. A 100 score home is described as "a house that is airtight, well insulated, sufficiently ventilated, and requires no purchased energy on an annual basis"[2].

The Rating System is coordinated with other related schemes and incentives, such as the R-2000 Standard (see Section 2.2.6) and ecoENERGY Retrofit. The ecoENERGY Retrofit program provides financial support to implement energy-saving projects. It is administered by the Office of Energy Efficiency and applies to all building sectors. The program provides grants up to $5,000 to homeowners to implement measures that will increase the energy efficiency of their home.

2.2.2 Home Energy Rating System Index (United States)

The Home Energy Rating System (HERS) is a nationally recognised system for inspecting, calculating and comparing a home's energy performance (RESNET, 2012). The rating is determined using a software package fed with data gathered through analysis of a home's construction plans and mid/post construction site inspections.

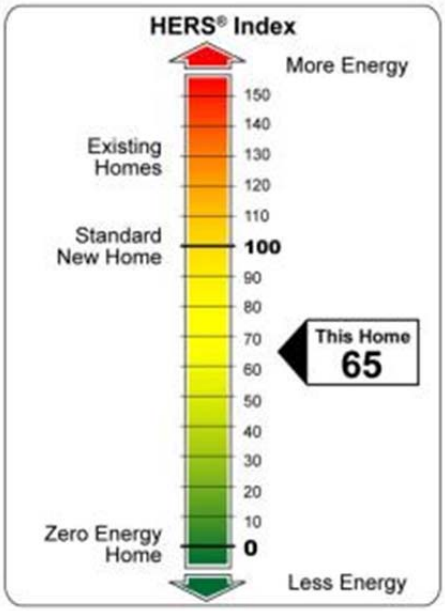
A standard new home, built to the 2006 International Energy Conservation Code, is used as a reference home and is awarded a rating of 100. A net zero energy home, which produces as much energy as it uses, scores a 0. The lower a home's HERS Index, the more energy efficient it is. Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home.

The HERS Index is visualised using the rating table shown in

Figure 1 below which provides an easily understandable means to compare the relative energy efficiency of different homes.

Figure 1 Home Energy Rating System (HERS) Index

[2] http://oee.nrcan.gc.ca/residential/personal/new-omes/upgrade-packages/energuide-service.cfm?attr=4



Source: http://www.resnet.us/images/content/yardstick_large.jpg

2.2.3 *UK Code for Sustainable Homes*

The UK Government's Code for Sustainable Homes (the Code) provides a national voluntary standard in the UK that aims to guide industry in the design and construction of sustainable new homes. The Code sets minimum standards for energy, amongst a range of other environmental factors. It has also been designed to support the UK Government's zero carbon policy goals (all new homes to be zero carbon by 2016), which have been recognised as the most ambitious world-wide (PRP Architects, 2010). The Code builds on the UK's Building Regulations, but is entirely voluntary. However builders are encouraged to build to the Code's sustainability principles in preparation for the Government's consideration to make assessment under Code standards mandatory (Department for Communities and Local Government, 2008).

The Code uses a one to six level rating system, where level 6 incorporates net zero CO_2, to communicate the overall sustainability performance of a new home. It measures the sustainability of a new home against nine categories of sustainable design: Energy/CO_2, Water, Materials, Surface Water Runoff, Waste, Pollution, Health and Well-being, Management, and Ecology. Information regarding each certified dwelling is taken from the Code Service Provider's databases and collated for the Department for Communities and Local Government by BRE Global Ltd on a monthly basis. The key characteristics of the Code include:

- Voluntary approach
- Aligns with the national target for all new homes to be net zero carbon by 2016 (and intermediate targets leading up to this such as Part L 2013)
- Establishes minimum energy standards for each of the six levels (where level six equates to zero carbon).

Changes to the Code have been recently made so that it aligns with the UK Building Regulations (see Section 3.3.2). For example, Code level 4 is now defined as a 25% improvement above the requirements of Part L 2010 of the Building Regulation.

Case Study: Zero Carbon House, Birmingham (http://zerocarbonhousebirmingham.org.uk/)

Location:	Birmingham, UK	**Type:**	4 bedroom semi-detached house (renovation)
Builder:	SpellerMetcalfe	**Size:**	Not available

The Zero Carbon House in inner city Birmingham meets the requirements of Level 6 of the UK Code for Sustainable Homes. The family home is an extension of a redbrick Victorian house, converting a 2-bedroom semi-detached 1840 brick house into a 4-bedroom dwelling with a studio loft. It extends upwards and outwards: upwards to catch the sun otherwise obscured by a taller neighbouring house, sideways for more space. The main features include:

- Triple glazed windows and double air seals
- Thermal wall insulation
- High airtightness, including use of membranes in walls
- High thermal mass using compressed earth blocks
- Passive design, using glazing for winter solar gain
- Low energy lighting and fittings
- Solar PV panels and solar hot water vacuum tube system
- Ventilation system using heat recovery from stale air to warm fresh air
- Wood burning stove.

The total cost of the home, which was half new build and half renovation, was £1,575/m^2 or about $2,500/$m^2$. The average cost of a new home in the UK is about £700/m^2. While the Zero Carbon house cost around double the cost of a typical new mass market home in Australia and the UK it is comparable to the cost of other bespoke homes. Nevertheless, this case study demonstrates that in the UK, as in Australia, zero carbon homes remain beyond the reach of the typical consumer.

2.2.4 The Passivhaus Standard

The Passivhaus (German) or Passive House (English) refers to a voluntary, ultra low-energy construction standard developed in the 1990's by the Passivhaus Institut, Germany. The standard has since gained significant acceptance with 30,000 passive houses worldwide[3], with >16,000 in Germany, of which 10 % have been certified by the Passive House Institute (http://www.passiv.de/07_eng/index_e.html).

A Passivhaus building[4] is one in which achieves thermal comfort solely by post-heating or post-cooling of the fresh air mass – without the need for additional recirculation of air[5]. International standard ISO 7730 is used to set the strict thermal comfort requirements that must be met. Limits are placed on building space heating/cooling demand, air-tightness of building envelope and the primary energy use. Measures used to achieve strict thermal comfort levels include:

- good levels of insulation with minimal thermal bridge,
- passive solar gains and internal heat sources,
- triple glazing
- excellent level of airtightness, and
- good indoor air quality, provided by a whole house mechanical ventilation system with highly efficient heat recovery (Building Research Establishment Ltd, 2011).

The Passivhaus Standard imposes no strict requirements on domestic hot water; lighting or appliance consumption. However the standard does impose an overall limit on a home's primary energy consumption in an effort to promote efficient operation of these elements.

Internationally, passive houses typically cost 3-8% more than conventional houses but, regardless of climate, deliver heating/cooling energy consumption savings of over 80% (International Passive House Association, 2010). The Passivhaus Standard can also be applied to renovations. However, experience to date demonstrates that renovating to the standard is difficult to achieve cost effectively (Building Research Establishment Ltd, 2011).

Recognising this, the EnerPHit Standard was developed to guide cost effective energy efficiency renovations. The EnerPHit Standard sets lower standards for specific heat demand (ie., ≤ 25 kWh/m².yr rather than the Passivhaus requirement of achieving ≤ 15 kWh/m².yr for specific heat demand) making it easier to achieve than Passivhaus but encouraging renovations to improve the energy efficiency of existing homes. A modelling software package called the Passive House Planning Package (PHPP) must be used to verify compliance with Passivhaus requirements. The Passive House Institute offers training and certification for Passive House designers, builders, assessors and building products.

The Passivhaus Standard represents one approach towards low carbon homes. Whilst not zero carbon in itself the reduced energy requirements of a Passive House allow smaller and cheaper quantities of renewable technologies to be specified to achieve zero carbon operational standards.

Adoption of the Passivhaus Standard has been greatly aided by the development of the International Passive House Association. This communication initiative provides a "one-stop-shop" for everything Passivhaus, promoting information exchange between stakeholders and fostering greater public understanding of the standard and its significance. Additional drivers include annual passive house conferences and house open days (700 passive houses were open to public in 2009), a publically accessible database of certified

[3] http://www.passivehouse-international.org/index.php?page_id=65

[4] Relates to a house that complies with the Passivhaus Standard, not be confused with a house that contains passive design features e.g. passive solar design, but does not comply with Passivhaus Standard (Building Research Establishment 2010)

[5] http://passipedia.passiv.de/passipedia_en/basics/the_passive_house_-_definition

designers/builders/assessors, completed buildings, performance certified building products, and university certified design and assessor courses. In some European countries financial assistance such as low interest loans, grants and income tax reductions are available for houses that comply with the standard (Bárta, 2009). Similar approaches are likely to aid the adoption of a move towards zero carbon homes in Australia.

2.2.5 *The Swiss MINERGIE standards*

MINERGIE is a brand; its main purpose is to act as a voluntary sustainability standard for new and refurbished buildings (http://www.minergie.com/home_en.html). A range of MINERGIE Standards have been launched since 1998, including MINERGIE-P (which defines buildings with "very low energy consumption" and corresponds to the passive-house standard) and MINERGIE-ECO (which includes additional sustainability features including recyclability). MINERGIE takes an objective-oriented approach, providing flexibility. Builders and planners have complete freedom in the design, choice of materials and choice of internal and external building structures to meet the requirements of the standard. The 15,000 buildings that have been certified as MINERGIE buildings demonstrate MINERGIE's success.

The success of MINERGIE buildings may be attributed to several features, which are drawn from an information guide developed for architects on the MINERGIE Standard for Buildings (MINERGIE, 2010), including:

- Objective orientated approach: builders and architects have freedom in what materials they use and their designs to meet the Standard. This approach is comparable to the 'Alternative Solutions' option set out in Australia's BCA, where builders have the freedom to meet minimum performance requirements in ways other than those set out in the 'deemed-to-satisfy' provisions. If the 'Alternative Solution' option is utilized, evidence of meeting the requirements must be provided. 'Deemed-to-satisfy' provisions describe "building solutions" that are assumed to meet the minimum requirements (no evidence is required).
- Strongly markets itself as a wise investment decision and a way of improving indoor living environment and comfort, guaranteeing a higher quality of life.
- All 26 cantons (States) are members of the MINERGIE Association and 19 of them directly promote it by offering subsidies for homeowners (opting to subsidise the strict MINERGIE-P standard, averaging $12,000 USD per new single family home).
- Requirement that the additional costs for MINERGIE® must not exceed 10 % of the building costs. This aims to demonstrate feasibility and wide spread use.
- Consistent messages: a board of 8 public figures and a president oversees the two operative directors of marketing and technology in their activities in Switzerland and abroad.
- Strong public-private partnership of MINERGIE with the Swiss economic sector, building industry and public agencies.
- Owned by a non-profit association, financed by its 380 members, who comprise of architecture firms, building and manufacturing companies and banks, services (certification, education and information programs, consulting and coaching) and its sponsors (companies of the Swiss construction industry, investors and different levels of government).
- World-renowned companies like IKEA are among members. IKEA has decided to build all new buildings in Switzerland according to MINERGIE.
- MINERGIE is in close contact with over 900 local businesses that are experienced in constructing according to the standard.
- It offers a wide range of products and services including MINERGIE modules and MINERGIE materials
- The building stock is sectored into 12 categories with different uses. Some of them have differing limiting values and all of them have their own standardised input data, such as indoor air temperature, air change rate, specific electricity demand etc. For all categories, significantly less stringent limiting values exist for the MINERGIE® renovation standard (e.g., 60 kWh/m2 for residential buildings).

- MINERGIE has developed a franchising concept – allowing a franchisee a very fast start in establishing a professional information, training and certification centre at moderate start up costs. This ensures a reliable financial base and ties with the local government.

Supporting the success of the MINERGIE Standard is a study that was conducted on 9,000 home sales in Switzerland, which found that those with the MINERGIE label achieved a sales price 7% higher than comparable homes without the label (Popescu, Bienert, Schützenhofer & Boazu, 2011).

2.2.6 *The Canadian R-2000 Standard*

The R-2000 Standard is a voluntary national technical performance standard used in Canada for energy efficiency, indoor air tightness quality and environmental responsibility in home construction and operation. It is administered by Natural Resources Canada (government body), is industry-endorsed and delivered through a network of service organizations.

The standard aims to promote the use of and demand for cost-effective energy-efficient building practices and technologies. R-2000 Standard requirements relate to both performance goals and prescriptive measures and cover: employing a builder with an R-2000 builder license, meeting an energy target, whole house ventilation system, utilization of the environmental pick list (every R-2000 builder must pick options from the 'pick list' for indoor air quality and environmental features), and independent inspections. The standard, which has been in practice since 1983, has led to the deployment of over 10,000 certified homes. Its success can be attributed to several factors:

- **Quality assured**: consistency and value are assured through third party evaluators and a government of Canada supported certification process
- **Flexibility**: the requirements are intended to give the builder flexibility in the selection of construction techniques, building products, mechanical equipment, lighting and appliances
- **Custom fit**: Energy target: local climate, energy sources and size of the house are all factored in when defining the energy target, which is unique for each R-2000 certified home. One tool is used to determine the target, the energy simulation software (HOT2000).

The Standard is subject to review every few years. The most recent version of the Standard is the 2005 edition, but the Standard is currently under review by the R-2000 Renewal Committee. The Committee, which is comprised of a balanced representation of expertise and interest groups, is now seeking comments from a broad range of stakeholders as to its recommendations for updating the Standard.

The Standard is also periodically updated to represent leading edge cost-effective housing technology. Government and industry manage R-2000 technology through consultations involving researchers, home-builders, product manufacturers and other housing experts. These partners meet regularly to review new housing research and determine if the Standard should be upgraded to reflect new developments. When changes are made R-2000 home-builders receive additional training and technical information to help them incorporate the new improvements.

2.2.7 *The canadian super-e standard*

Super-E® is a housing standard (http://www.super-e.com/), which builds on the R-2000 Standard and other Canadian housing programs, to deliver commercially attractive energy efficient, comfortable and healthy housing. Super-E homes utilise high quality designs, products and systems that adhere to strict performance and warranty standards, ensuring extremely durable buildings that operate efficiently and provide high levels of indoor air quality and comfort. Super E has been developed by three science based agencies - Natural Resources Canada, Canada Mortgage and Housing Corporation and National Research Council Canada, who collaborate with other housing partners to accelerate its uptake and ensure its applicability for an international market.

Introduced to the UK in 2000, over 500 Super-E houses had been built by 2008. Several construction

companies in the UK have been certified to deliver Super-E houses, including Sunley Holdings plc, Berkeley Homes Ltd., and Kelsey Housing Association Ltd. Discussing the challenge of moving the standard to market, Jeff Culp from the Super-E office identifies the significance of strong marketing efforts for generating awareness, interest and demand for Super-E homes and for government support. He comments "there were some very unfounded perceptions that needed to be addressed and we have spent a lot of time through training programmes, marketing, PR and giving key note presentations at leading industry events and architectural universities. Through education, Super-E has gone a long way towards changing those initial perceptions and of course with climate change the need was finally apparent that our ideas needed to be incorporated into Part F and Part L legislation."

The website that exists for the standard (see: http://www.super-e.co.uk/index.htm) offers ideas for how to market low impact homes. Ideas for marketing and raising consumer awareness are outlined in more detail in Section 5.5.

2.2.8 US Voluntary Standards

There are numerous voluntary standards for home energy performance in the United States. These include

- The National Association of Home Builders ICC 700 National Green Building Standard™ (http://www.nahbgreen.org/), which requires that homes achieve a minimum HERS rating of 100 and awards emerald, gold, silver and bronze levels for homes that achieve higher ratings. For example, a gold rating requires a 40% reduction from the minimum Green Standard, which equates to a HERS index of 60.
- The Department of Energy's Builders Challenge (http://www1.eere.energy.gov/buildings/challenge/) encourages homeowners to decrease energy use by 30% to earn a HERS index number of 70 (see Section 3.3.5 for more details).
- The US Environmental Protection Agency's Energy Star program for homes (http://www.energystar.gov/index.cfm?c=new_homes.hm_index) requires that a home is at least 15% more energy efficient than homes built to the 2004 International Residential Code (i.e. HERS index of 85) and includes additional energy saving features that typically make the home 20-30% more efficient than a standard home. The HERS index requirements vary according to climate zone.
- The US Green Building Council's Leadership in Energy and Environmental Design (LEED) rating tool requires certified homes to achieve a HERS index rating of at least 85 and provides additional points for homes that exceed this rating. LEED certified homes are typically 30-60% more energy efficient than a standard home (Shultz, 2008).

The plethora of voluntary standards in the United States creates healthy competition between standards but is likely to also result in market confusion.

2.2.9 Climate Positive Development Program

The Clinton Climate Initiative (CCI) and US Green Building Council launched the Climate Positive Development Program in May 2009. The Program supports the development of precinct-scale urban projects that demonstrate the ability of cities to grow in "climate positive" ways. The Program aims to set a new global benchmark for leadership in large-scale urban development. One of the requirements for participating developments is that they work to reduce the amount of on-site CO_2 emissions to below zero by generating more renewable energy than total net greenhouse gas emissions, recycling and exporting more water than used and reusing, reducing and recycling more waste than is generated.

The Program adopts a partnership approach, where developers and local governments work with the CCI to deliver climate positive communities. The CCI provides technical support, business and financial analysis, and partnership facilitation. Initially, 17 projects are part of the Program including developments in Melbourne (Victoria Harbour) and Sydney (Barangaroo); Palhoça, Brazil; Toronto and Victoria, Canada; Ahmedabad and Jaipur, India; outside Panama City, Panama; Pretoria and Johannesburg, South Africa; Seoul, South Korea;

Stockholm, Sweden; London, U.K.; and San Francisco and Oberlin, Ohio in the United States. Around one million people will live in these communities once they are complete.

Although geared towards large-scale precinct developments, the Program has the potential to generate broader change by testing zero carbon innovations and helping to build economies of scale for new materials, technologies and techniques.

2.2.10 One Planet Living

One Planet Living is a global initiative based on 10 principles of sustainability developed by Bioregional and WWF (http://www.oneplanetliving.org/index.html). One of the ten principles is that communities should be zero carbon, which would be achieved by making buildings more energy efficient and delivering all energy with renewable technologies.

The One Planet Communities program works with private and public property developers to create a network of green neighbourhoods. Communities that apply the principles can seek endorsement from Bioregional. BedZed in the UK was a prototype application of the One Planet Living principles. Since then, four communities in the UK, USA and Portugal have become endorsed One Planet Communities and seven others, including the Barangaroo development (NSW) in Australia, are applying the principles. Regions and organisations can also apply the One Planet principles.

2.2.11 The 2030 Challenge

Architecture 2030 is a non-profit, non-partisan and independent organisation established to rapidly transform the U.S. and global building sector from the major contributor of greenhouse gas emissions to a central part of the solution to the climate change, energy consumption, and economic crises. Architecture 2030 established the 2030 Challenge (http://architecture2030.org/2030_challenge/the_2030_challenge), which asks the global architecture and building community to adopt the following targets:

- All new buildings, developments and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 60% below the regional (or country) average for that building type
- At a minimum, an equal amount of existing building area shall be renovated annually to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 60% of the regional (or country) average for that building type
- The fossil fuel reduction standard for all new buildings and major renovations shall be increased to:
    - 70% in 2015
    - 80% in 2020
    - 90% in 2025
- Carbon-neutral in 2030 (using no fossil fuel GHG emitting energy to operate).

These targets may be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power and/or purchasing (20% maximum) renewable energy.

The Challenge has been adopted by the American Institute of Architects, the US Conference of Mayors, the US Green Building Council and numerous other industry associations, universities and businesses in the United States. Some State governments (e.g. Washington State and New Mexico) and numerous cities and counties (e.g. Seattle) have also adopted the Challenge.

2.2.12 The Net-Zero Energy Home Coalition (Canada)

The Net-Zero Energy Home (NZEH) Coalition (http://www.netzeroenergyhome.ca/) is a Canadian multi-stakeholder organization comprised of champions in advanced energy efficient residential construction and building products, the utility sector, research and development, and manufacturing and deployment of onsite renewable energy technologies. The Coalition aims to drive low and zero energy homes by facilitating the

uptake of existing energy efficiency and renewable energy technologies. The NZEH Coalition's approach is to work with and support market leaders and other stakeholders who are interested in delivering zero carbon homes.

Implementation Plan

The NZEH Coalition recently released (March 2011) the *NZEH Industry Implementation Plan*, which aims to provide a strategy for achieving a net-zero energy standard for all new homes by 2030 (Winkelmann, 2011). The Implementation Plan sets out details on a prioritized list of 22 key activities, which are grouped into five general categories:

- Technical standards and quality assurance
- Technical support tools
- Training and capacity building
- Marketing and promotion
- Financing.

The task of prioritizing key activities was a joint effort by all key stakeholders. This input is assisting the Coalition to strategically direct its resources and efforts to initiatives that will most effectively drive and support the net zero energy residential market. The initiatives that are detailed in the plan are identified as 'immediate (2011), short-term (2012-2013), and medium-term (2014-1015) activities. Immediate activities include:

- Develop an industry endorsed net-zero ready (NZR) and net-zero energy home definition with quantifiable performance metrics
- Undertake a modest marketing effort with key partners targeting early adopter consumers to support members
- Consolidate existing baseline consumer market research to support the development.

The delivery of the plan is intended to be a collaborative effort by all stakeholders, led by the NZEH Coalition. For each activity, the plan identifies potential key stakeholders and partnerships to drive them. To ensure that the Implementation Plan is effective, the Coalition has expressed plans to establish and facilitate a long-term working group with industry and government stakeholders and form task forces whose members reflect the diverse stakeholders in zero-energy homes (builders, manufacturers, suppliers, utilities, trade and industry groups, academia, government, home buyers and financial institutions).

Technology Roadmap

- The Implementation Plan builds on a *Technology Roadmap in Sustainable Housing*, which is yet to be published. Industry Canada, a Canadian government department, promotes and guides the development of technology roadmaps across a range of industries. Industry Canada's aim is to transform Canadian industries to be more productive, innovative and competitive. Industry is encouraged to develop technology roadmaps by following three phases. Phase 1 considers feasibility and resources. Phase 2 identifies actions for the development and commercialization of technologies. Phase 3 involves periodic evaluations, re-thinking and cultural adoption. Industry is further encouraged to identify key stakeholders to drive the different initiatives that make up the roadmap and to detail all anticipated benefits.

A technology road map enables the industry to:

- Predict the market's future technology and product needs
- Identify critical enabling technologies and where gaps exist
- Signal skills requirements and regulatory roadblocks
- Increase collaboration and partnerships
- Establish a framework to coordinate research and development (R&D) and leverage investments
- Provide sector and supply chain information for small to medium enterprises (SMEs).

The NZEH Coalition has received significant support from government, industry and financial institutions, and demonstrates the significance of effective collaboration between these and other key stakeholders in creating a stimulating environment for achieving ambitious net-zero energy goals. The Coalition also demonstrates the value of creating a national platform to share experience and knowledge and provides ideas on effective membership structures and marketing of a national body that coordinates NZEH goals. ASBEC could play a similar role to the Coalition and the Implementation Plan may act as a great starting point for the development of a roadmap for realizing ASBEC's zero carbon home goals for Australia.

Case Study: South East False Creek Net Zero Building (http://www.thechallengeseries.ca/chapter-07/net-zero/)

Location: Vancouver, Canada
Builder: City of Vancouver
Type: Multi-residential building (67 units)
Size: 55m^2 per unit (1 bedroom)

The Net Zero Building at South East False Creek in Vancouver, Canada is an eight-storey seniors' residence with 67 units, including 6 street-level townhouses. It is the first multi-unit residential net zero carbon building in North America. The City of Vancouver led the project with support from the Canadian Mortgage and Housing Corporation. It was developed as athlete accommodation for the 2010 Winter Olympics, to become affordable housing after the Olympics. The main features include:

- Maximising cross-ventilation and daylight by putting corridors and stairs on the perimeter of the building and giving every suite two external walls
- Vertical ventilation shafts at negative pressure to expel air from apartments passively
- Triple pane windows
- External insulation of walls, with thermal mass inside to regulate temperature
- Slab insulation
- Green roof to reduce cooling requirements and provide recreational space
- Evacuated tube solar water heating generating heat equivalent to 90% of the annual energy consumption
- Sale of excess hot water to adjacent properties via Neighbourhood Energy Utility
- Occupant engagement via energy meters in suites and user manuals
- Use of discarded heat from the refrigeration system of a neighbouring grocery store to preheat water
- Sewage heat recovery
- Auxiliary natural gas boilers.

By selling excess heat in the summer to offset lower solar gain in winter, the Net Zero Building achieves a zero annual carbon balance.

The City of Vancouver established minimum requirements under LEED to encourage sustainable buildings in the precinct. This included requirements for the overall rating and for specific credits. The South East False Creek neighbourhood received a LEED Platinum rating.

Perhaps the most valuable lesson from the Zero Net Building is that achieving zero carbon for a multi-unit residential building is difficult in isolation. It is the connections to adjacent buildings, enabled by establishing a Neighbourhood Energy Utility, that have made zero carbon possible. This demonstrates the importance of adopting a precinct scale to drive zero carbon developments and reform of electricity laws to support building-scale utilities.

Data on the cost of this building is scarce but there are indications that the additional cost per unit was about $40,000, which is in the order of 10% of the average selling price of $436,500. Based on other projects, it is likely that the City of Vancouver and its partners supported the project with direct incentives and subsidised loans.

2.2.13 World Business Council for Sustainable Development

The World Business Council for Sustainable Development (WBCSD) is a CEO-led, global association of approximately 200 companies drawn from 30 countries. It provides a platform to explore sustainable development and advocate business positions on these issues. In April 2009, the WBCSD released the *Energy Efficiency in Buildings: Transforming the Market* report (WBCSD, 2009) as part of its Energy Efficiency in Buildings project (EEB). The report modelled energy use in residential and commercial building stock in six of the world's largest economic regions, (Brazil, China, EU, India, Japan and USA), which represent almost two-thirds of the world's energy use. The report included recommendations and an actionable roadmap to cut energy use in buildings by 60% by 2050, and interestingly, concluded the necessary changes to make these savings cannot be made through market forces alone.

The EEB modelling showed increasing the price of energy or carbon will only slightly increase the implementation of energy-efficiency in buildings with a shift from today's energy prices to a carbon cost of US$ 40/ton reducing buildings carbon footprint only 3%. The report also draws a comparison between the cost of implementing building life safety codes and the associated compliance measures, currently adds 5% to building costs in the US, with the global net cost for the required transformation of building sector estimated at 7% of current annual building construction costs.

Relevant recommendations from the EEB report for the implementation of zero carbon homes in Australia are listed below:

- Introduction of gradually strengthening regulation for energy efficiency in new and existing homes, supported by revised building energy codes detailing energy efficiency requirements for homes, appliances and building materials, independent home performance auditing and on-site renewable energy generation.
- Provision of tax breaks and incentives for energy efficiency investments with longer payback periods. Modelling showed only one third of the investments required to meet the 60% reduction in building energy use have discounted payback periods of 10 years or less.
- Provision of incentives for developers to produce energy efficient buildings with stipulation building energy efficiency is gained by a holistic approach.
- Creation of a zero carbon home vocational training within the building industry using programs specifically developed for those who build, renovate and maintain buildings. In addition, targeted training is recommended for "system integrator" professionals. Once trained, these "integrators" would create whole-house energy efficiency retrofitting plans and co-ordinate the individual specialised building retrofitters to undertake the work.
- Implement a sustained education campaign to promote consumer behavioural change and increase awareness of the impact of energy use in buildings and the energy efficiency options available. Communicate energy usage and performance information for all public buildings.
- Create mechanisms to reward energy utilities for end-user energy savings e.g. white certificate scheme.
- Property tax reduction for energy-efficient behaviour compared to building label's expected performance
- Pay as you save – the energy utility pays for energy efficiency retrofit and recoups the outlay through regular surcharges on the monthly bill; these surcharges are attached to the house, not the specific customer
- Local Government provides loans to finance the energy efficiency retrofit and repayments are made through an addition to land tax payments (WBCSD, 2009).

2.3 Discussion

The above discussion indicates that there are only a handful of existing voluntary initiatives in Australia that explicitly aim to deliver zero carbon homes. These include the South Australian Land Management Corporation's Zero Carbon Challenge, the Australian Zero Emission House Project and several demonstration homes. Cost data from the demonstration homes indicates that low and zero carbon homes are not yet able to compete beyond the high-end housing market.

NatHERS and its associated rating tools are used to assess compliance with the National Construction Code (see Section 3.1.3) but can also be used voluntarily to assess the heating and cooling performance of existing buildings or to demonstrate performance beyond compliance. CSIRO released its new AccuRate Sustainability tool in May 2011, which provide a regulated heating and cooling assessment but moves towards a more complete assessment of sustainability performance by including modules on hot water, lighting and water use. The other main voluntary rating programs are Green Star and NABERS. The former only applies to multi-residential buildings, not to individual dwellings. The latter is a simple tool for assessing energy performance relative to a benchmark. None of these tools explicitly target zero carbon and their voluntary uptake in the residential sector is low.

With mandatory disclosure of energy performance for homes still under discussion, the future role of voluntary rating tools in driving zero carbon homes remains very uncertain. Green Star has been particularly successful in driving sustainability innovation for commercial office buildings, where there is strong recognition of Green Star ratings in the market and developers aim for particular Green Star ratings as a way of gaining attention and attracting buyers or tenants. There is strong market demand for commercial buildings with high Green Star ratings (GBCA, 2011). However, the same level of market demand does not exist at this time in the residential sector and there is no single dwelling-specific Green Star tool.

Should mandatory disclosure of energy performance for residential buildings be introduced (see Section 3.1.4), householders will start to become more familiar with a particular rating approach at the dwelling level. Ideally, future voluntary rating systems would be able to build on the mandatory system, using similar methods and language. This will be crucial to avoid marketplace confusion, while providing additional incentives to go beyond mere reporting of energy performance.

Leading international voluntary initiatives on zero carbon homes include voluntary energy and carbon standards for single homes (e.g. Passivhaus, MINERGIE, R-2000, Super E, the UK Code for Sustainable Homes and several voluntary standards in the United States) and precinct-scale developments (e.g. Climate Positive and One Planet Living), voluntary targets (e.g. the 2030 Challenge) and coalitions established to facilitate the emergence of zero carbon homes (e.g. the Net Zero Energy Home Coalition in Canada and the World Business Council on Sustainable Development's Energy Efficiency in Buildings project). It is clear from these international examples that Australia could pursue additional voluntary standards, targets and competitions to engage the building industry in the task of improving home energy and carbon performance. There will also continue to be a role for progressive builders and developers to demonstrate what is possible and it is important to support sustainability champions in this work and to consolidate experience with these homes into a resource for other builders to draw on.

Canada's Net Zero Energy Home Coalition is of particular interest as a possible model for coordinating voluntary action. This multi-stakeholder coalition recently released a Net Zero Energy Home Industry Implementation Plan, which outlines a strategic approach for achieving a net zero energy standard for all new homes by 2030.

The voluntary UK Code for Sustainable Homes and the work of the Zero Carbon Hub also provide valuable insights into issues that Australia could consider in setting and delivering on zero carbon goals. Key lessons include:

- The need to align voluntary and regulatory schemes (so that they complement and support each other)
- The value of adopting consistent language and assessment methods throughout all initiatives that relate to and support zero carbon ambitions
- The use of voluntary schemes to build initial momentum and incentivise action that will help to achieve subsequent regulatory requirements.

One important point to note is that most of the voluntary initiatives around the world focus primarily on delivering new zero carbon homes, rather than retrofitting existing homes to achieve a zero carbon standard.

3 GOVERNMENT SUPPORT FOR ZERO CARBON HOMES

This section examines the role of government support in facilitating delivery of zero carbon homes. Government support can take different forms, including establishment of targets, supportive policy and regulation, or provision of grants and incentives. Section 3.1 examines Australian policy and regulation with the potential to support the emergence of zero carbon homes. Section 3.2 considers government grants and incentives that could support zero carbon homes. Section 3.3 investigates leading international practice in government support for zero carbon homes. Section 3.4 discusses options for improving Australian government support for zero carbon homes.

3.1 Australian Policy and Regulation

The National Strategy on Energy Efficiency, discussed in Section 3.1.1, provides overarching policy direction on energy efficiency for Australian homes. As one of the key actions from the Strategy, the Australian Government is in the process of establishing a National Building Energy Standard-Setting, Assessment and Rating Framework (National Building Framework) to provide more detailed policy guidance for energy performance in the building sector through to 2020 (Senior Officials Group on Energy Efficiency, 2010). The Framework is discussed in Section 3.1.2. The primary mechanism for implementing regulatory standards for buildings, including energy efficiency standards, is the National Construction Code, discussed in Section 3.1.3.

Other key actions under the National Strategy on Energy Efficiency include a proposal for mandatory disclosure of residential building energy, greenhouse and water performance (see Section 3.1.4) and various appliance energy regulations (see Section 3.1.5). The Australian Government's Clean Energy Future package also includes some initiatives with the potential to support zero carbon homes, as discussed in Section 3.1.6. These include the Clean Energy and Other Skills Package, discussed in Section 3.1.7. Further, the Australian Government's National Carbon Offset Standard (see Section 3.1.8) may have a role in determining what kind of emission reduction measures can be used to achieve zero carbon homes.

Finally, State Governments have some State-specific schemes that are relevant to the emergence of zero carbon homes and are responsible for implementing requirements under the National Construction Code. While none of these schemes directly target the delivery of low carbon homes they are relevant in lifting the baseline for energy performance. State initiatives are discussed in Section 3.1.9.

3.1.1 National Strategy on Energy efficiency

In 2009 the Council of Australian Governments (COAG) released the National Strategy on Energy Efficiency (NSEE) (Council of Australian Governments, 2010). The NSEE aims to encourage and facilitate a coordinated approach to innovation and uptake of energy efficient technologies (including appliances), approaches and behaviours across the commercial, residential and industrial building sectors. The NSEE is broken down into four key themes, each with a number of measures, which outline a pathway and identify responsible bodies to drive and support key elements of each measure. Themes 1, 2 and 3 are particularly relevant to the delivery of zero carbon homes in Australia and are discussed below.

Theme 1: Assisting households and businesses to transition to a low carbon future

Measures under this theme that relate to zero carbon homes aim to provide material assistance and information and skills that will facilitate improvements in efficient use of household and business energy. Key elements under this theme relate to:

- Industry capacity building
- Increasing innovation in energy efficient technologies
- Increasing consumer awareness of the availability and benefits of energy efficiency technologies and appliances
- Improving national data gathering and reporting.

An initiative that has already been undertaken under this theme is the development of a long-term training strategy for energy efficiency assessment skills by the National Framework for Energy Efficiency (NFEE) Commercial and Industrial Implementation Group. Actions from the strategy were incorporated into a National Energy Efficiency Skills Initiative and now form part of the Clean Energy and Other Skills Package, announced by the Gillard Government as part of its Clean Energy Future package (see Section 3.1.6).

Theme 2: Reducing impediments to the uptake of energy efficiency

Measures under this theme that relate to zero carbon homes aim to support demand-side initiatives, and increase energy efficiency standards for appliances and the transport sector. Key elements under this theme relate to:

- Delivering useful information to consumers and businesses that will drive energy efficient behaviours and encourage uptake of energy efficient technologies
- Increasing research into impediments for investing in demand side management and encouraging increased investment into a more efficient energy network.
- National legislation for Minimum Energy Performance Standard (MEPS) and labelling.

Current initiatives to enable more informed consumer decisions relating to energy use include the new and revised standards for MEPS and labelling and increased compliance monitoring and enforcement. Expansion decisions are involving key stakeholders and reference to international best practice. The body responsible for this initiative is the NFEE Equipment Energy Efficiency (E3) Committee.

Theme 3: Making buildings more energy efficient

Measures under this theme that relate to zero carbon homes aim to provide consistent standards and performance assessment frameworks and encourage voluntary action by providing valuable information about building energy efficiency. Key elements under this theme relate to:

- Mandatory disclosure of residential building energy, greenhouse and water performance at time of sale or lease (see Section 3.1.4)
- The development of an integrated national outcomes-based framework for energy standard setting, assessment and rating framework (to be implemented from 2011, see Section 3.1.2)
- Increasing the coverage and stringency of energy efficiency provisions for all new residential buildings
- Incentives for residential building owners to undertake energy efficiency improvements
- Auditing of energy efficiency of public housing stock and implementing cost-effective upgrades
- Addressing opportunities for renewable energy at building lot or precinct scale.

3.1.2 National Building Framework

The National Building Energy Standard-Setting Assessment and Rating Framework (The National Building Framework) will aim to address measure 3.1.1 of the NSEE, which states that "all jurisdictions will work together to develop a consistent outcomes-based National Building Energy Standard Setting, Assessment and Rating Framework for driving significant improvement in the energy efficiency of Australia's building stock – to be implemented in 2011" (Senior Officials Group on Energy Efficiency, 2010). The Discussion Paper to the National Building Framework identifies that measure 3.1.1 is the key buildings measure in the NSEE.

The National Building Framework is currently in draft form and consultation is continuing before its release, due this year. However, the Framework Discussion Paper (Senior Officials Group on Energy Efficiency, 2010) and our interviews provide a strong indication of the key features of the final Framework, which include:

Outcomes-based

- The National Building Framework will be designed to achieve measurable objectives. This will involve setting clear goals and allowing flexibility in how to achieve these goals (within limits, e.g. certain materials or processes could be regulated out).

- The National Building Framework appreciates the complex inter-relations between energy use, greenhouse gases, peak demand, energy efficiency and human comfort in buildings. In response the Framework aims to incorporate several outcomes in the future and fit these together as a clearly communicated and practical system.
- A range of objectives will be introduced over time, with initial focus on greenhouse gas and energy efficiency performance. Peak loads and embodied energy are identified as potential outcome based goals to be incorporated in the future.

Coverage principles

- The National Building Framework will cover new and existing buildings and all classes of commercial and residential building stock. Appreciation of the need for different standards amongst these different building types is given.
- The Framework Discussion Paper identifies the significance of including all phases of the building life cycle in the National Building Framework but notes the current complexity and difficulty of doing this. In response, it suggests initial focus on operational aspects of the building and a later expansion of coverage to include embodied emissions and emissions resulting from construction and deconstruction phases.

Increasingly stringent minimum performance standards for new buildings and major renovations

- Standards will be reviewed periodically, for example every three or five years, and will continue out to meet 2020 goals. Long-term goals and early standard setting will increase market certainty and facilitate effective adjustment as it provides industry with the time and confidence it needs to invest in capacity building and innovative practical and cost effective solutions.
- The pathway to achieving 2020 goals will involve several incremental increases in the standards. Some submissions to the Framework Discussion Paper agree with few but larger steps as ideal for the purpose of creating greatest change and allowing for adjustment time – industry learning, technological development.
- Different pathways for different building types were discussed as an option in the Framework Discussion Paper.
- Energy efficiency requirements to be used for regulatory purposes are set out in the Building Code of Australia (BCA) and thus changes will be subject to the normal BCA amendment process (regulatory impact assessment).

Assessment and Rating tools

- The National Building Framework recognizes the diverse range of building standards and assessment and rating processes to manage energy performance of buildings across Australia and seeks alignment of these where feasible and desirable (to the extent that confusion is minimized and efficiencies are gained). Differences exist both between and within jurisdictions. Considerations include:
    - Specifying consistent but not necessarily identical approaches to assessing the energy performance of different building classifications;
    - As far as practicable, aligning rating scales and benchmarking processes;
    - Accounting for variations in climate and emissions factors in different regions of Australia;
    - Developing appropriately robust administration and governance systems for rating tools and assessors; and
    - Accommodating mandatory disclosure of residential building energy, greenhouse gas emissions and water performance at time of sale or lease.
- The National Building Framework calls for consistent communications on building rating, standards, and assessment tools to help to cause a paradigm shift within the building industry (in what they are designing and constructing) and the building owners and renters (in purchasing decisions and how they use the building).

Assuring quality assessors and industry skills

- Initiatives to ensure quality assessors, e.g. training programs, provide opportunities for consistently communicating zero carbon concepts and language. This relates to the potential to also link in with measure 1.2.1 of the NSEE – the development of a National Energy Efficiency Skills Initiatives.

3.1.3 National Construction Code

The National Construction Code (NCC) regulates the Australian building and plumbing sectors. It comprises the Building Code of Australia (BCA) and the Plumbing Code of Australia. The Australian Building Codes Board (ABCB) maintains and updates the NCC and supports COAG in delivery of regulatory reforms for the building sector. The ABCB is a joint initiative of all levels of government in Australia, with representation from industry.

The BCA contains technical provisions for the design and construction of buildings and other structures, covering such matters as structure, fire resistance, access and egress, services and equipment, and energy efficiency as well as certain aspects of health and amenity. It sets performance standards and defines standard practices that are 'Deemed to Satisfy' those standards, while also allowing 'Alternative Solutions' to encourage innovation. The BCA is updated annually in response to proposals for change received from governments, other organisations or the public.

Minimum thermal performance standards for residential buildings were first introduced into the BCA in 2003 and have been progressively tightened over time. Substantial changes were introduced in BCA 2010, requiring all new homes to achieve a 6 star energy rating under NatHERS and establishing additional requirements relating to water heating and lighting. Major changes to the BCA, like these, require preparation of a Regulatory Impact Statement (RIS) and public consultation. In general, the regulatory impact process must establish that the changes will have a net benefit using the discount rates and costing rules established for such processes. The impact of the changes introduced in 2010 varies depending on the home from a net saving of up to $8,025 to a net cost of $2,240 (Centre for International Economics, 2009).

The NCC is given legal effect through state and territory building legislation. Individual state and territory legislation determines the buildings and new building work to which the energy efficiency provisions apply. Implementation varies significantly by state and territory. NSW requires new homes and renovations to comply with its Building Sustainability Index (BASIX), which established more comprehensive requirements than the BCA. Other jurisdictions have implemented the 6 star requirements, although sometimes with specific concessions (e.g. Queensland requires a 6 star energy equivalence rating but provides star credits for solar power and outdoor living areas) and transition periods (e.g. Western Australia is phasing the requirement in between May 2011 and May 2012).

The National Building Framework (see Section 3.1.2) is expected to establish a future pathway for further updates to energy efficiency requirements in the BCA.

3.1.4 Mandatory disclosure of residential building energy, greenhouse and water performance

As noted in Section 3.1.1, the National Strategy on Energy Efficiency commits to phase in the mandatory disclosure of residential building energy, greenhouse and water performance, subject to the results of regulatory analysis. This proposed measure would require the owners of houses, flats or apartments to provide energy, water and greenhouse performance information about the home at the time it is offered for sale or lease. This measure is potentially very important to the future delivery of zero carbon homes, as it could drive consumer demand for more efficient homes and build familiarity with home energy and greenhouse rating systems. The measure is due to be phased in from 2012, starting with energy performance.

The Regulatory Impact Statement (Allen Consulting Group, 2011) for this proposed measure was recently released for consultation, with the submission period closing on 12 September 2011. It presents six options for mandatory disclosure:

- Option 1: full thermal assessment based on thermal performance simulation and other building component information
- Option 2: simplified thermal assessment based on a simplified thermal performance simulation and other building component information
- Option 3: self assessment online tool, using simple online thermal assessment and other building component information
- Option 4: self assessment checklist, based on building component information only.
- Option 5: Non-regulatory response including a consumer information campaign
- Option 6: Assessment with Opt-out provision

Option 2 is assessed as having the most positive economic outcomes, although there is significant uncertainty about assumptions. Option 1 would be most accurate for assessing progress to a zero carbon goal but has a negative cost-benefit analysis and falls short of providing a comprehensive assessment of energy and carbon performance. The Regulatory Impact Statement (RIS) does mention the possibility of revising NatHERS to give a broader rating of energy and carbon performance, or using a Home Sustainability Assessment calculator tool to provide the performance rating for mandatory disclosure. However, such a tool does not currently exist and no details are provided on how it would be developed and what coverage it would aim for. At this early stage, with many details still to work out, it is hard to say whether mandatory disclosure will help to drive demand for zero carbon homes or lock in a narrow rating that works against broader definitions of zero carbon homes.

Another key point to note is that there is no requirement at this stage for jurisdictions to introduce mandatory disclosure requirements in a nationally consistent way. There is potential for different approaches in different jurisdictions.

3.1.5 *Appliance energy regulation*

Appliance energy regulation has a role to play in moving towards zero carbon homes, particularly when using broader definitions of zero carbon homes that include energy use by appliances. Australia has a well-established system of regulation for appliances, including white goods, air conditioners, water heaters, televisions and compact fluorescent lamps. Policies are implemented through a collaborative initiative called the Equipment Energy Efficiency Program (E3) involving representatives drawn from all jurisdictions in Australia and New Zealand.

Many appliances must comply with mandatory Minimum Energy Performance Standards (MEPS) and display Energy Rating Labels (ERLs). A comprehensive approach to achieving zero carbon homes would need to look at opportunities to strengthen MEPS and potentially expand the application of ERLs. If the focus is on building-incorporated services then requirements for water heaters, space heaters, air conditioners and fixed lighting are of particular interest.

3.1.6 *Clean Energy Future Package*

The Australian Government released the Clean Energy Future Package in July 2011, announcing plans to introduce a carbon price on 1 July 2012 of $23 per tonne with a move to an Emission Trading Scheme (ETS) from 1 July 2015. The policy includes a number of complimentary measures and household assistance relevant to the shift towards zero carbon homes.

The Low Carbon Communities (LCC) will be expanded to include three initiatives with total funding of $300 million. The low Income Energy Efficiency Program (LIEEP) will provide financial support for energy efficiency approaches to assist low-income households overcome energy efficiency barriers. Up to $100 million in competitive grants will be provided to consortiums of local and state governments, community organisations, energy retailers and energy service companies, to fund 15 to 20 trial projects to assist identified low-income households. The Department of Climate Change and Energy Efficiency will administer the LIEEP.

An extension of the $200 million LCC program to support energy efficiency upgrades to council and community-use buildings, facilities and lighting. This imitative is not covered in further detail, as it does not relate directly to residential buildings.

The Household Energy and Financial Sustainability Scheme (HEFS) will provide $30 million to help around 100,000 low-income households find more sustainable ways to manage their energy consumption. The package includes: energy and financial sustainability assessments and advice, financial education and money management, and access to the no interest Loan Scheme to assist with the purchase of more energy efficient appliances.

The HEFS will be administered by the Department of Families, Housing, Community Services and Indigenous Affairs, which has released a HEFS discussion paper and is currently consulting on the proposed design of the Scheme. The department has proposed the Scheme include a range of assistance including:

- New educators to provide energy efficiency and financial management advice
- Access to existing energy efficiency schemes provided by energy providers, state and territory governments and the not-for-profit sector
- Access to Emergency Relief and Commonwealth Financial Counselling; and
- Microfinance options to assist low-income households with the purchase of more energy efficient appliances. In particular, funding for the No Interest Loans Scheme (NILS) will increase by $5 million over four years to provide more loans for household goods that will improve energy efficiency for households under the Scheme.

Implementation of these policies will provide an opportunity to build experience in retrofitting existing homes for the move towards zero carbon. Current details on these initiatives are scant however and further information will be required before their full role in a move to zero carbon homes may be appreciated.

Information regarding the incentives will be communicated through the Government's LivingGreener website (www.livinggreener.gov.au) which currently provides information on Commonwealth, state and territory initiatives such as the Renewable Energy Bonus (solar/ heat pump hot water grant) and appliance energy and water efficiency labelling.

Further initiatives announced include a working group to undertake further research on a transitional national Energy Saving Initiative (ESI or "white certificate scheme"). If implemented a national ESI would replace existing state energy efficiency in NSW, Vic and SA, subject to Council of Australian Governments (COAG) approval. The ESI involves placing obligations on energy retailers to deploy household and business energy savings measures and would encourage the up take of energy efficient technologies helping to develop the service industry required to supply and install these technologies. If paired with a move to zero carbon homes an ESI would aid existing home retrofits and consumer education of the energy efficiency options. An Australian Bureau of Statistics (ABS) survey aimed at gathering and communicating data on household sector energy consumption will inform the research with the ESI working group to report the results of the work in the first quarter of 2012.

3.1.7 The Clean Energy and Other Skills Package

To increase industry capacity to deliver quality clean energy services and products, the Australian Government announced in July 2011 the Clean Energy and Other Skills Package, to be administered by the Department of Education, Employment and Workplace Relations. The Package will deliver up to $32 million over four years to skill up engineers, financial and facility managers and other tradespeople and professionals operating within the clean energy industry. The Package intends to promote the business case for energy efficiency, drive low-cost energy efficient design and products, and ensure that existing buildings operate as energy efficiently as possible.

There are four key elements to the Package.

1. Baseline mapping project - which will be undertaken during 2011-2012 to identify skills gaps within key industries responsible for the delivery of energy efficiency services and evaluate the best ways to build the needed capacities.

2. Trades training - relevant Industry Skills Councils will use data obtained from the baseline mapping project to develop priority skills sets for the building industry that will enable it to deliver and promote quality energy efficiency services and products efficiently. Training resources for VET (Vocational Education and Training) practitioners in RTO's (Registered Training Organisations) will also be developed under this element.

3. Professional training – funding will be available for the development of a technical energy efficiency module as part of a university undergraduate engineering qualification.

4. Integration for energy efficiency skills - this element provides support during 2011-2012 for projects that enhance the energy efficiency and clean energy skills of workers in the building and construction industry.

There are opportunities for ASBEC to advocate to ensure that the skills needed to deliver zero carbon homes are supported under the Clean Energy and Other Skills Package.

3.1.8 National Carbon Offset Standard

Where it is not possible or cost-effective to achieve a zero carbon standard on-site, some programs allow the use of emission reductions elsewhere to reach zero carbon. While purchase of carbon offsets should be a lower priority than achieving on-site energy savings or installing clean energy, it may contribute to meeting zero carbon standards in some circumstances. In such cases, the quality and reliability of the carbon offsets is crucial. The Australian Government's National Carbon Offset Standard (NCOS) is a voluntary standard that sets out requirements for carbon offsets that aim to ensure their environmental integrity and provide consumers with certainty about the quality of offsets they purchase (DCCEE, 2009).

The NCOS sets minimum requirements for calculating, auditing and offsetting the carbon footprint of an organisation or product for the purpose of achieving carbon neutrality. It also provides guidance on what constitutes a genuine, additional voluntary offset. Where carbon offsets are allowed in a zero carbon initiative, they should at a minimum comply with the NCOS. In practice, this means that carbon offsets need to be accredited under one of the Kyoto Protocol mechanisms, the Gold Standard, the Verified Carbon Standard or, in the future, the Australian Government's Carbon Farming Initiative or emissions trading scheme.

3.1.9 State and Territory regulation

As noted in Section 3.1.3, State and Territory governments are responsible for implementing the requirements of the National Construction Code and often adopt different approaches. This section briefly surveys the different approaches in different jurisdictions to highlight the diversity in current approaches. It is not intended as a comprehensive coverage of all State and Territory building regulation but draws out key differences.

Queensland

The Queensland Government's sustainable housing laws require new houses and townhouses, and major renovations to existing buildings, to achieve a minimum 6-star energy equivalence rating, and new unit buildings and major renovations to units must achieve a 5-star energy equivalence rating. The energy equivalence rating can be achieved through expert review, implementation of elemental provisions of the BCA or using software accredited under NatHERS.

A key point of difference in Queensland is that the following optional credits are available to achieve the required star rating:

- A credit of up to one star is available for inclusion of an outdoor living area. Half a star is available if the outdoor living area is fully covered, connected to an indoor living area and meets size, insulation and other requirements. A full star is available if the area is fitted with at least one ceiling fan.

- A credit of one star is available for houses and townhouses that include a photovoltaic energy system with a minimum of 1-kilowatt capacity.

NSW

The NSW Government uses the online Building Sustainability Index (BASIX) tool to assess home design in terms of energy and water consumption against region specific targets. The BASIX targets require a residential development proposal to use up to 40% less potable water and produce up to 40% fewer greenhouse gas emissions than the average NSW home. The proposal must also pass a thermal comfort evaluation (NSW Department of Planning, 2006). The energy and thermal comfort targets vary according to building type and location and the water target incorporates regional variations such as soil type, climate, rainfall and evaporation rates.

The BASIX tool uses information such as site location, house size, building materials, water heating and fittings, home cooling/heating and alternative energy and water sources to calculate the BASIX score. The design for a residential proposal must meet the targets before a BASIX Certificate is issued. Commitments made during the BASIX process must appear on the plans and be adhered to during the building process (compliance is checked by a building inspector).

From July 2007, all residential developments (Inc. swimming pools) throughout NSW with a total estimated cost of works of $50,000 or more require a BASIX certificate to obtain a Complying Development Certificate (CDC), however only the renovated section of the house is must be covered by the BASIX certificate.

Unlike other jurisdictions, the NSW Government does not require homes to achieve a specified star rating under NatHERS. BASIX is intended to deliver equivalent or superior results to the 6 star standard established in the BCA. BASIX is a more comprehensive tool than NatHERS, covering both greenhouse gas emissions and water and taking into account more than just thermal performance. However, some interviewees argued that NatHERS provides a more rigorous assessment of thermal performance than BASIX.

BASIX Post-Implementation Cost-Benefit Analysis undertaken in 2009 showed the cost for a dwelling to comply with BASIX ranges between $1,114 (for a Sydney high rise unit) and $21,902 (for a single detached house in the Southern Highlands with no gas). The compliance cost for an average Sydney Western Suburbs house was estimated at $6,417.

Total per dwelling benefits expected to accrue to households by 2050 was estimated at between $3,273 (for a Sydney high-rise unit) and $14,661 (for a large Sydney house relying on solar power to pass BASIX) (NERA Economic Consulting and BMT Quantity Surveyors, 2010).

Case Study: Eco-living Net Zero Emissions Home

Location: The Ponds, Sydney **Type:** 2 bedroom detached house
Builder: Clarendon Homes **Size:** 149.8 m^2

The Eco-living Net Zero Emissions Home is a collaboration between Clarendon Homes (the builder) and Landcom (the land and funding provider). The home has a modelled 8-star NatHERS rating and is aimed to appeal to the project home market. Inclusion of a solar electricity generation system and energy efficient appliances complete the homes net zero carbon occupied design. The main features include:

- Good design orientation and shading
- Reverse brick veneer construction
- Roof and wall insulation
- Low E double glazing for all windows and doors
- Gas boosted solar hot water system
- Energy efficient LED and fluorescent lighting
- Inverter technology A/C (split system)
- Gas cooktop
- Energy efficient appliances (Fridge, washing machine and dishwasher all minimum 3.5 star rating)
- Ecomax 1 concrete (20% fly ash content)
- Low embodied energy bricks (25% lighter)
- 4.5 kilowatt solar electricity generation system
- Grey water system backed-up by local recycled water supply, 10,000 L underground rain water tank and water efficient appliances and fixtures.

Clarendon has not yet released cost information for the Eco-living Net Zero Emissions home as it is yet to be launched. The home is scheduled to be open to the public in January 2012.

Victoria

Victoria adopted the 6-star standard in the BCA from 1 May 2011. The building surveyor's responsibility includes confirmation that the plans meet the 6-star standard. This is a straightforward implementation of the BCA requirements.

Western Australia

Western Australia's approach is very similar to that of Victoria, with the exception of the timing. Western Australia is allowing a 12-month transition period before Councils require new homes to comply with the BCA 2010 requirements, which means the standard will not be enforced until 1 May 2012.

3.2 Grants and Incentives

In addition to policy and regulation, governments can support the transition to zero carbon homes by providing grants and incentives. The Australian Government provides numerous grant programs and rebates that have the potential to support zero carbon homes, or specific technologies used in zero carbon homes. For example, the Renewable Energy Bonus Scheme – Solar Hot Water Rebate provide rebates of up to $1,000 to eligible households that replace their electric storage hot water systems with solar hot water systems. A comprehensive list of Australian Government rebates and programs is available at http://www.climatechange.gov.au/government/programs-and-rebates.aspx.

State Governments also provides grants and incentives that can help to facilitate delivery of zero carbon homes. Many States and Territories provide solar feed-in tariffs that pay a premium rate for gross or net generation by photovoltaic panels installed in homes. However, several of these schemes have recently been terminated or scaled back.

The Australian Government and some State and Territory Governments also provide subsidised energy audits and energy efficiency retrofit programs.

We have not attempted a comprehensive review of existing grants and incentives in this report. It is sufficient to note that most grants and incentives to date in Australia target the householder, rather than the builder, and that there is scope to develop new incentive programs that would be better targeted to delivery of zero carbon homes.

3.3 Leading International practice

This section reviews leading international practice in government support for delivery of zero carbon buildings. The leading initiatives identified are the European Directive on Energy Performance of Buildings (Section 3.3.1), the United Kingdom's Building Regulations (Section 3.3.2), Canada's National Building Code and National Energy Code for Housing (Section 3.3.3), Building Codes in the United States (Section 3.3.4), Building America's Zero Energy Homes Initiative (Section 3.3.5) and California's Long Term Energy Efficiency Strategic Plan (Section 3.3.6).

3.3.1 European Directive on Energy Performance of Buildings

The European Directive on the Energy Performance of Buildings is the main legislative instrument to establish energy performance standards for European homes. It was recast in 2010 (Directive 2010/31/EU) to require all new buildings in member states to be 'nearly zero-energy buildings' by 31 December 2020. No specific target has been set for the renovation of existing buildings but Member States are advised to take measures for stimulation of low energy refurbishments.

Case Study: Tevesstraße, Frankfurt

Location: Frankfurt, Germany **Type:** Multi-unit dwelling (renovation)

Builder: ABG Frankfurt Holding **Size:** 53 apartments, average size 65 m^2

This renovation of two postwar apartment buildings in Frankfurt achieved a 94% reduction in heating demand and almost met the Passivhaus Standard, which is impressive for a renovation in an apartment building. The buildings contained 60 apartments and were in a bad state. The renovated buildings contain 53 apartments ranging from 33 to 100 m^2 in size. Key features of the renovation included:

- Exterior insulation and finish system
- Insulation of basement ceiling
- Modification of the ground plans
- New attic floor, wooden light-weight construction, completely insulated
- Passive house suitable windows (triple glazing)
- Decentralised mechanical ventilation appliances with heat recovery installed in each apartment
- Improved efficiency of the airtight layer. Air change rates were reduced from 4.4 per hour to 0.46.
- Efficient reduction of thermal bridges
- New electrical and sanitary installation
- Solar hot water and one solar heat pump, backed up by gas condensing boilers.

Before the renovation, heating demand was 290 kWh/m²a and primary energy demand was 375 kWh/m²a. After the renovation, these were reduced to 17 and 49 kWh/m²a respectively, reductions of 94% and 87%. Data on the costs of the renovation are not available.

Perhaps most importantly, residents now praise the development and enjoy living there (http://passipedia.passiv.de/passipedia_en/operation/operation_and_experience/residents_experiences).

A 'nearly zero-energy building' is defined as one that has a very high energy performance and meets its remaining energy requirements to a very significant extent using energy from renewable sources, including energy from renewable sources produced on-site or nearby. The energy performance of a building can be based on calculated or actual annual energy use required for heating, cooling and hot water. It is the responsibility of member states to implement the requirements and decide on the details.

Many European countries have responded with targets to deliver zero carbon homes, including:

- The United Kingdom, which requires new homes to be zero carbon by 2016. A recent review of progress towards a series of timelines to support the delivery of the 2016 target identifies that whilst 'some progress' has been made 'urgent action' is now required to achieve the ambitious goals (Zero Carbon Hub, 2011b).
- France intends all new buildings to be energy-positive by 2020
- Germany, which aims for all new homes to operate without fossil fuels by 2020
- Hungary, which is targeting zero emission buildings by 2020
- The Netherlands, which plans to build energy neutral by 2020 (European Commission, 2009).

Many of these targets are relatively recent so it is difficult to assess progress at this time. However, one of the main lessons from the European experience is the value of regulating a long-term policy objective with interim steps, providing industry with sufficient certainty to invest in new technologies and practices to move towards that objective.

3.3.2 *UK building regulations*

The UK regulates technical requirements for energy efficiency within its built environment through its national Building Regulations. Whilst the requirements within each UK nation may differ slightly they all share the ultimate goal of reducing home energy and CO_2 emissions.

Regulation 17C requires new homes to be designed to have a *dwelling emission rate* (DER) that is less than the *target CO_2 emission rate* (TER) (HM Government, 2010). The TER is expressed as the mass of CO_2 (kg) attributed to the *fixed building services* (any part of the dwelling that relates to fixed internal or external lighting systems, and fixed systems for heating, hot water, air conditioning or mechanical ventilation) for a standardised household, per m^2 of floor area, per year. The regulations specify the methodology that is to be applied in calculating the TER. In the case of apartments, Regulation 17C is satisfied if either the average DER is no greater than the average TER, or every individual dwelling has a DER that is no greater than its corresponding TER.

Regulation 20D requires that the person carrying out the work must give the local authority a notice, within five days before commencing construction, that specifies the TER, the DER and a list of specifications that will enable the dwelling to perform to the DER. As part of the compliance procedure a software tool is used to identify the specifications that are critical to achieving the DER. This helps the party responsible for confirming compliance to prioritise what parts of the dwelling to inspect if an inspection process is carried out. Regulation 20E also requires that within five days of completing the construction a notice is provided to the local authority that specifies the emission rate of the dwelling *as constructed* and whether the building has been built in accordance with the specifications initially provided and if not how it has departed. The local authority then may accept the notice as evidence of compliance, which must be signed off by an accredited energy assessor.

Regulation 17E requires that when a new building is built or a renovation takes place that satisfies certain conditions (i.e., modification that alters or adds to the fixed building services), the builder shall give an energy performance certificate for the building to the owner and give notice of the energy performance certificate to the local authority. The regulations also require that an energy performance certificate is accompanied by a recommendations report that makes recommendations as to how to improve the energy performance of the dwelling. The energy performance certificate must be issued by an energy assessor accredited to issue such certificates and must detail the asset's DER rating and a reference value such as the current legal standard.

Part L requires reasonable efforts to be made to limit heat losses and gains through the building envelope and fixed services systems. Additionally, in an effort to educate consumers and help ensure buildings are operated in an efficient manner, Part L requires that sufficient information is provided to the owners of the dwelling that will encourage and enable them to operate the building as efficiently as possible. Builders are encouraged to ensure that this information includes a set of user-friendly instructions on how to operate and maintain the dwelling so that it operates efficiently; the instructions should be in a durable format and relate specifically to the systems compromising the dwelling.

Practical guidance documents (Approved Documents), for meeting the requirements of the Building Regulations, are issued by the Secretary of the State. These documents describe what compliance may look like in ordinary circumstances and what actions will be considered as reasonable efforts for complying with the requirements. The Approved Document for energy efficiency requirements provides guidance on designer flexibility, explaining that the TER can be achieved through a combination of fabric and systems measures and the integration of low and zero carbon technologies, including community renewable energy projects that the dwelling is connected to, noting that Schedule L does require minimum standards of thermal performance of the building envelope and fixed building services. Guidance is also provided on how to determine an appropriate mix.

To encourage action beyond the minimum standards set by the Building Regulations other policies and voluntary initiatives exist, including the UK Code for Sustainable Homes, which was detailed in section 2.2.3. As noted above, the UK has set a target for all new homes to be zero carbon by 2016 and intends to progressively tighten Building Regulations to achieve this target. It is important to note that the UK process has not been trouble-free. The ambitious initial goal to achieve zero carbon for all operational energy use has recently been scaled back to exclude occupant-related energy use and emissions.

The Zero Carbon Hub specialist task group, a UK public/private partnership, was established in 2008 to support the UK's zero carbon policy goals. Since this time the Zero Carbon Hub has conducted and released a stream of valuable research that has helped to inform a strategy for delivering on the UK's zero carbon objectives. In February 2011, the Zero Carbon Hub released a report (Zero Carbon Hub, 2011a), which laid down key elements for such a strategy. In essence it recommended a hierarchical approach where high levels of energy efficiency are first pursued (starting from the design phase); then set levels of the residual energy must be generated by on-site low or zero carbon technologies; and lastly the remaining energy must be offset through allowable solutions (essentially carbon savings away from the site – detail on allowable solutions is currently being developed). The first two stages make up what the Zero Carbon Hub refers to as the carbon compliance limit. Different limits have been recommended for three different building types (detached homes, attached homes, and low-rise apartments). High rise apartments and mixed use buildings have been recognised as posing unique issues and requiring potentially different treatment, which requires further investigation – also subject of current research. Further detail on carbon compliance limits is provided in previous research conducted for ASBEC's ZERTG (Riedy, Lederwasch & Ison, 2011).

3.3.3 Canada National building code and National Energy code for housing

The design and construction of new buildings and renovations made to existing buildings are regulated in Canada through six codes released by the Canadian Commission on Building and Fire Codes (CCBFC). Two codes relate specifically to energy efficiency in housing, these are the National Building Code and the National Energy Code for Housing. The National Energy Code for Buildings covers energy requirements for non-residential buildings. To have effect in a province these Codes must be adopted by the appropriate authority in that province. On adopting the codes the provinces have authority to amend the codes so that they are appropriate for the context of that province.

The 2010 National Building Code is an objective-based code, whereby all requirements relate to one of four key objectives (safety, health, accessibility, and fire and structural protection of buildings). In a response to the request to add energy efficiency objectives to the National Building Code, the CCBFC conducted an analysis,

involving a broad range of stakeholders, and determined that the addition of such an objective is appropriate as it would complement existing environment policy goals including resource conservation, reduced emissions, infrastructure capacity and energy security and the policy goal of harmonization. In addition, CCBFC recognised that many jurisdictions had begun adding energy efficiency related requirements to its building regulations.

A new version of Canada's 2010 National Building Code, which will incorporate energy efficiency requirements in its Part 9 housing, is to be published in mid to late 2012. Development of the new requirements is currently being conducted by CCBFC, who is receiving technical and financial support from other government agencies, including Natural Resources Canada, and other stakeholders. The equivalent energy efficiency provisions in the updated National Energy Code for Buildings were approved earlier this year and are due for publication at the end of 2011.

The proposed changes applying to houses and small residential properties are intended to address building envelope, heating, ventilation, air conditioning and hot water. Additional requirements relating to lighting and electrical power are planned for larger residential and non-residential buildings. Three different compliance paths will be available; a prescriptive path that will focus on construction areas foreseen to cause energy efficiency challenges, such as air tightness; a path that will compare the energy performance of the proposed house to a reference house (one that fulfils prescriptive requirements) utilizing energy modelling of the proposed house; and a more flexible path that gives designers and builders freedom to meet certain energy efficiency goals through different materials, systems and techniques. Flexibility in meeting energy efficiency performance has been identified as an important element of the National Energy Code for Buildings.

In accordance with usual code procedures in Canada individual jurisdictions will be free to adopt and adapt the energy efficiency provisions of both codes to suit individual jurisdictional goals and contexts. The CCBFC offers guidance to each jurisdiction for adapting the codes.

3.3.4 *US Building Codes*

There is no single Building Code regulating the energy performance of homes in the United States. In the past, many different Codes proliferated across different state and local governments. More recently, however, the development of Model Codes has brought a degree of standardisation. The International Code Council (ICC) publishes the International Energy Conservation Code (IECC), which is a model code that state and local governments can adopt. A new 2012 IECC has just been approved which will require energy performance 30% greater than the 2006 IECC, resulting in a HERS index score of 70.

Many state and local governments have adopted the IECC but there are substantial differences in the version of the IECC code that is followed from state to state (Shultz, 2008). For example, Indiana follows a model code that dates from prior to 1992, Arizona follows the equivalent of a 2003 IECC model code and California follows a model code that is between the 2006 IECC and 2012 IECC. Some states have no building codes and rely on local governments to establish building codes. As in Australia, there is no consistency in implementation of energy performance requirements across the United States.

3.3.5 *Building America's Zero Energy Homes initiative*

Building America is part of the US Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE), Building Technologies Program (BTP). The program is a partnership between Federal, State and local Government, the private sector, and universities and national laboratories. Research from this program is used to accelerate the development of whole-house measures for energy-efficient new and existing homes, tailored for each major U.S. climate region. Ultimately, BTP's R&D and deployment efforts aim for "affordable, energy-efficient homes by 2020 and high-performance commercial buildings by 2025."

The Building America program has produced many publications including climate specific best practice guides, case studies, an online database of current and completed projects, research articles and software designed to identify lowest cost optimally efficient designs for new and existing homes. As of March 2011, the online

projects database shows 42,136 homes that utilise technologies and strategies developed through Building America.

From the vast amount of research, literature and information produced as part of the Building America program, two initiatives stand out as being especially relevant to the implementation of zero carbon homes in Australia. The first is the Builders Challenge that began in 2008. The Challenge is voluntary initiative where the homebuilding industry is "challenged" to build an increasing number of high performance homes that achieve a 70 or better on the EnergySmart Home Scale (E-Scale). The E-Scale is based on the HERS Index discussed in section 2.2.2 and uses the same scale. An E-Scale score of 70 means a home uses at least 30% less energy than a typical new home built to code. The E-Scale allows homebuyers to understand – at a glance – how the energy performance of a particular home compares with others. A clever marketing tool employed by the homebuilder is placing a graphical depiction of the home's E-Scale score (shown in

Figure 1) near the home's meter box.

To take part in the challenge, homes must be third-party verified as complying with the Builders Challenge Quality Criteria. Through the Builders Challenge, participating homebuilders differentiate their best energy-performing homes from other products in the marketplace, and have a way to make the benefits of these homes clear to buyers. They are also given the opportunity to participate in program events and awards and provided access to the Builders Challenge Marketing Toolkit that provides an array of marketing tools for builders to promote their participation and raise consumer awareness of their high performance homes.

The initiative acts as a communication, marketing and educational tool for Building America best practice research, engaging builders, product manufacturers and consumers and ultimately driving demand in the market for low carbon homes.

The second is a report released in June 2009, titled Making Homes Part of the Climate Solution: Policy Options to Promote Energy Efficiency. Sponsored by the U.S. Climate Change Technology Program (CCTP) and undertaken in coordination with DOE BTP and Office of Electricity Delivery and Energy Reliability the report explores the development of policy options to improve energy efficiency in residential buildings, with supporting analysis informed by behavioural research.

Selected compelling policy recommendations taken from the paper are detailed below:

- Revise building energy codes and provide financial assistance to establish and expand training and certification programs focused on third-party verification of building energy code compliance. Aimed at addressing the split incentive between builders and building owners. Increased energy building code compliance reduces lost opportunities for energy efficiency that were affordable only at the point of construction.
- Develop a national home energy reporting method providing uniform data reporting. A national standard acts as an enabler, decreasing information asymmetry between builders and building owners, users or buyers and lowering market risks for builders to comply with revised energy codes.
- Require disclosure of home energy consumption or home energy performance at the point of sale or lease of a residential home (in conjunction with standard national home energy reporting method).
- Provide financial assistance to State Energy Offices to establish revolving loans for on-bill financing for energy efficiency improvements with no up-front costs to homeowner using a "pay-as-you-save" approach for repayments. Loan responsibility is linked to the house, not owner.
- Increase energy usage information flow to consumers – install smart meters that supply a "read-out" of usage. Note, this approach must be paired with a dynamic time of use-based energy pricing model.
- Implement a national energy saving initiative with the onus on energy retailers to implement savings. This approach must be paired with regulation decoupling retailer/distributor revenues from increased electricity sales. Instead energy retailers/distributors must make more revenue by implementing the energy saving initiatives.

3.3.6 *California's Long Term Energy Efficiency Strategic Plan*

California has the most ambitious energy targets for homes in the United States. In September 2008, the California Public Utilities Commission adopted a Long Term Energy Efficiency Strategic Plan (Engage360, 2011), laying out a roadmap to achieve energy savings across all major groups and sectors in California. Under the Plan, there is a vision for energy efficiency improvements to deliver zero net energy new buildings by 2020, with interim targets for 2011 and 2015.

California intends to achieve these targets through:

1. Building Innovation: Drive continual advances in technologies in the building envelope, including building materials and systems, construction methods, distributed generation, advanced metering infrastructure, and building design, and incorporate technology advances into codes and standards.
2. Comprehensive Solutions: Develop, offer and promote comprehensive solutions for single and multi-family buildings, including energy efficiency measures, demand management tools and real-time information, and clean distributed generation options in order to maximize economic decision-making and energy savings.
3. Customer Demand: Create high levels of customer demand for progressively more efficient homes through a coordinated state-wide public education campaign and targeted incentive programs.
4. State-wide Solutions: Coordinate and collaborate with state agencies and private organizations to advance research and development and to align state efforts on buildings.
5. Financing: Work with the financial community to develop innovative and affordable financing options for energy efficient buildings and retrofits.
6. Codes and Standards: Adopt aggressive and progressive minimum energy codes and standards for buildings and plug loads, effective code compliance and enforcement, and parallel, tiered voluntary energy efficiency standards that pull the market along and set a higher bar for subsequent standards.

3.4 Discussion

Australian policy and regulation for the building sector is constantly changing. The National Construction Code regulates the residential building sector and the National Strategy for Energy Efficiency is driving the development of several new policy initiatives, including the preparation of a National Building Energy Standard-Setting Assessment and Rating Framework and the proposed mandatory disclosure of home energy performance from 2012. However, until the release of the Framework, which has been delayed, the future structure of building sector regulation remains uncertain.

It is not yet clear whether the Framework will establish long-term energy and greenhouse targets for buildings, or will merely establish a timeframe for review of standards in the National Construction Code over the coming decade. COAG is likely to make a decision on this in the first half of 2012, so there is still an opportunity for ASBEC and its members to influence the decision. Many of the international regulatory processes reviewed here indicate the value of establishing a long-term policy objective, with interim targets, as a way of providing industry with certainty and a framework for innovation. There are some indications that simply having a long-term target in place is sufficient to start a process of cost reductions in delivering zero carbon homes, as it provides economies of scale through a long-term guaranteed market. However, to successfully influence future regulatory targets, ASBEC needs to be able to demonstrate a business case for zero carbon homes in Australia. This issue is considered in more detail in Section 5.3.

The feasibility of reaching zero carbon for all new homes by 2020 remains uncertain. The UK is aiming for 2016 and the government released its first proposals on this target in 2006. A recent review of progress towards a series of timelines to support the delivery of the 2016 target identifies that whilst 'some progress' has been made 'urgent action' is now required to achieve the ambitious goals (Zero Carbon Hub, 2011b). California is aiming for 2020 and released its plan in 2008. A California Energy Efficiency Progress Report identifies that whilst there have been some significant successes, including the growing number of California's zero net

energy buildings each year, there is a 'real risk' that the Strategic Plan goals will not be reached (California Energy Division, 2011). The Canadian Implementation Plan released in 2011 is targeting 2030. Whilst no progress reports are yet available Natural Resources Canada has begun the Affordable Net Zero Energy Homes Project in recognition that cost will be a major barrier to mainstream uptake.

Based on this international experience and the difficulties other nations are finding in meeting their stated targets, it could be argued that Australia has left it a bit late to start planning towards a 2020 target. Further, some of our interview participants spoke of fierce industry resistance to a zero carbon pathway and a lack of political will to go down that path. A 2025 zero carbon target, with interim targets in 2015 and 2020 implemented through tightening of the BCA requirements, may be a more feasible pathway given that there is still substantial work to do on developing a suitable rating tool. Although it is worth noting that, given the speed to market and success of the Green Building Council of Australia's (GBCA's) suite of Green Star tools, a new residential rating tool could be developed, tested and implemented quickly.

Other measures from the NSEE have the potential to support zero carbon homes, such as increasing energy efficiency requirements for appliances and the collection of actual data on energy efficiency of existing housing stock in Australia to inform energy efficiency policy. Whilst ABSA has data on the home energy ratings done by its members and BASIX has data on its ratings, more data related to housing energy efficiency, including how low and zero carbon homes perform, may help ASBEC to develop a strategy to drive low and zero carbon homes and prioritise its actions. Other NSEE measures that have potential to support zero carbon home goals include the provision of financial and resource support to homes for improving energy performance.

One of the clearest messages from our research is that there are industry concerns about the quality, coverage and auditing of current rating tools used to assess compliance with BCA requirements and the corresponding state and territory regulations. Significant regulatory differences between states and territories also increase compliance costs and the potential for market confusion. The National Building Framework considers the possibility of moving away from NatHERS to a broader rating tool; many interviewees noted the value of doing so. The current consultation on mandatory disclosure of energy performance for homes represents an opportunity to develop and implement a new rating tool covering a greater proportion of operational energy use, to establish reliable compliance and auditing mechanisms and to move towards nationally consistent energy efficiency requirements for buildings. It is vitally important to take up this opportunity, as the rating approach specified for mandatory disclosure is likely to be locked in for quite some time. There is also no guarantee at present that the states and territories will adopt a consistent approach to mandatory disclosure, which would further increase compliance costs and marketplace confusion.

The Australian Government Clean Energy Future package includes initiatives that will specifically support industry skills and retrofitting of existing homes to improve their energy and carbon performance. There is potential to influence the delivery of these initiatives so that they contribute towards the emergence of zero carbon homes and help to build the skills needed to deliver such homes.

Leading international regulatory initiatives include the European Directive on Energy Performance of Buildings (requiring "nearly zero energy" homes by 2020), the United Kingdom's plan to require all new homes to be zero carbon by 2016, California's Long-Term Energy Efficiency Strategic Plan (which has a goal for all new residential buildings to be zero net energy by 2020) and Canada's new provisions in the National Building Code and National Energy Code for Buildings to require energy efficient houses.

Although the regulatory context in these jurisdictions is not directly comparable to Australia, there are some valuable strategic lessons about how to implement regulation of zero carbon homes. First, it is critical to establish a consistent, long-term timeline and targets for increasing building energy performance standards to provide industry certainty and drive innovation.

Second, there are substantial barriers to overcome in moving towards zero carbon homes and there is value in having a dedicated organisation to undertake research, education and industry capacity building to overcome these barriers. The UK Zero Carbon Hub, chaired by Paul King (CEO of the UK Green Building Council), provides

an excellent model that could be emulated in Australia with support from the Green Building Council of Australia.

Third, the most successful international approaches use consistent mandatory and voluntary standards based on the same rating systems. Governments, for example in Canada and the United Kingdom, have provided the coordination to ensure alignment of voluntary and mandatory standards. Australia has several different rating tools that measure different aspects of residential building performance and would be better served by establishing a single national rating tool that provides a broad measure of operational energy and carbon performance. It is the role of government to provide the necessary coordination and long-term regulatory certainty, whereas industry may be best placed to deliver the actual rating tools. For example, the GBCA has a wealth of experience in developing rating tools.

4 THE MARKET FOR ZERO CARBON HOMES IN AUSTRALIA

Australia's housing stock comprises approximately eight million homes, with an estimated 130,000 new homes built each year (DCCEE, 2011). The size of Australian homes has been growing and the DCCEE predicts that the size of homes will continue to grow, although some of our interviewees have observed a reversal in this trend in recent times, as home owners begin to prioritise location over size. Nevertheless, the DCCEE expects energy consumption in homes to grow by more than 55 per cent between 1990 and 2020 on current trends (DCCEE, 2011). Given these trends, it is crucial that new homes are built to perform with high standards of energy efficiency and existing homes are renovated to enable improved energy performance. How homeowners use their homes is also of great importance.

A significant focus in our interviews with stakeholders was the state of the market for low and zero carbon homes. This section discusses current demand for zero carbon homes (Section 4.1), the cost effectiveness of zero carbon homes (Section 4.2), consumer awareness of zero carbon homes (Section 4.3) and the capacity of the building industry to deliver such homes (Section 4.4).

4.1 Current demand for zero carbon homes

Consumer demand for low and zero carbon homes in Australia is generally low. Most low and zero carbon homes are either demonstration homes or are delivered for high-end consumers of bespoke homes. Some of our interviewees reported increased demand for low or zero carbon homes, mainly driven by rising electricity prices. However, this increase in demand was mainly coming from people who are well informed of the existing low and zero carbon opportunities, are aware of the associated potential energy savings and have sufficient financial capacity to pay the additional upfront cost of such homes. Some interviewees argued that demonstration homes were also starting to drive some consumer demand. However, the evidence available to date (including sales figures) does not support this view. Of course, demand for low and zero carbon homes is not uniform across Australia. Demand is higher in some regions due to different expectations in different markets. For example, the Perth market expects double brick housing and this makes it easier to achieve high NatHERS ratings for less additional costs. As a result, demand for low or zero carbon homes is higher in Perth than elsewhere in Australia. These leading markets may provide niches to develop new technologies and practices and bring costs down before delivery in other markets.

Overall, however, consumer demand for zero carbon homes is low, for several reasons:

- Low and zero carbon homes are not yet seen as good value for money in most markets
- Consumer awareness of the benefits of low and zero carbon homes is low
- The building industry lacks the skills to deliver low and zero carbon homes.

Each of these issues is discussed in more detail below.

4.2 Value for Money

Perhaps the largest barrier to widespread adoption of zero carbon homes remains cost. In most markets, our interviews indicate that low and zero carbon homes are not yet cost-effective. Even with rising energy prices, payback periods for zero carbon homes are too long for most consumers and raising additional capital can be difficult, even if it makes financial sense over time. While cost is a barrier at present, the future trends are in the right direction, with energy prices rising and the cost of renewable energy technology falling.

Case Study: Jade909

Location: Perth **Type:** 3 bedroom detached house

Builder: Right Homes **Size:** 212.869 m²

Jade909, was designed by Jade Projects, built by Right Homes, sponsored by Think Brick and received assistance in promotion by Multiplex. It was built as a display home with the aim to educate and inspire consumers and designers/builders about available and affordable energy efficiency and on-site renewable energy products. The main features include:

- Double clay brick
- Passive solar design
- Quality energy-efficient appliances, fittings and saving devices throughout
- 3-kilowatt photovoltaic solar power generation system
- Recyclable building materials with optimal thermal mass qualities
- Grey-water recycling system and gas solar-boosted water heater
- Low E glass
- Roof and wall insulation
- Common sense approach to low embodied carbon, for example use of flyash concrete, and low environmental impact products, such as bamboo flooring

Jaded 909 achieved a 9 star NatHERS rating using the Building Energy Rating Scheme. However, as it is a display home we are not able to assess its actual performance. If operated as designed, the Jade909 home is expected to generate more energy than consumed on an annual basis (i.e., a net positive energy house).

Whilst Jade909 is promoted as cost-effective, Jade Projects and Right Homes explained that achieving a 9 NatHERS star rating involved increased costs, mainly due to the low E glass ($5,000), cavity wall insulation ($4,000) and increased ceiling insulation ($1,000), though this should negate the need for an air conditioner and thus lead to a significant reduction in running costs. The total cost of the Jade909 home was $220,000. Jade Projects stated that this reflects roughly an increase of $8,000 compared to a high quality finished standard home. Jade Projects went on to explain that a 7 star home can be achieved through the use of double brick and standard roof insulation by the masses at no extra cost (though this may be the case for WA alone due to its history and continued demand for double brick homes). It should be noted that renewable energy systems are an additional cost to these amounts.

Right Homes has recently built two 10 NatHERS star rating homes on consumer demand but explains that the clients are well educated and concerned about foreseeable electricity price increases. Both cases equated to an extra $50,000-$60,000.

Data on the additional cost to deliver a zero carbon home is highly variable in different markets. Drawing on their experience with the Australian Zero Emission House project, Henley estimates that the additional cost of a zero carbon home is $40,000, or 15%, resulting in a payback period of 11 years (Henley, pers. comm., 10 August 2011). While the Australian Zero Emission House included some extra features such as an extensive building monitoring and management system and a charging point for an electric vehicle, these cost estimates have been adjusted to remove these additional features. To date, Henley has only had two orders for zero energy homes, which equates to about 0.1% of the total volume built (Henley, pers. comm., 5 March 2012).

Our interviewees indicated that few homebuyers are willing to accept a payback of more than 5 years and there are few innovative financing mechanisms at present to overcome the barrier of the initial capital cost. Many homebuyers are stretching their budget as far as they can go to afford a home in a desirable location and feel that additional energy saving features are a luxury they cannot afford. In a recent survey examining the housing preferences of more than 700 residents in Sydney and Melbourne, respondents indicated that size and location were the most important factors in the choice of a home (Kelly, Walsh & Weidmann, 2011). However, it is important to point out that the survey did not include any specific mention of low energy costs or low environmental impact so it may underestimate the value that people place on zero carbon homes. There is very little solid market research on the value that people place on low or zero carbon homes and this is an area that requires further research.

If payback periods need to come down to 5 years or so, a long-term strategy to drive down the cost of zero carbon homes is essential. Setting a long-term regulatory pathway to zero carbon homes would help, as it provides investors and suppliers with sufficient certainty about future demand to make business decisions that reduce costs.

Much of the cost of delivering a zero carbon home is associated with solar panels used to supply residual energy needs once energy efficiency has been maximised. These are responsible for a significant portion of the additional capital outlay. Costs of solar panels have been falling rapidly in recent years and this will contribute to reduced payback periods over time. Solar feed-in tariffs can help to further reduce payback periods, however, state implementation of such schemes has been inconsistent. A uniform national feed-in tariff would be preferable. Predicted energy price rises will also reduce payback periods, making low and zero carbon homes more attractive over time. In other words, the trends are in the right direction for making zero carbon homes much more attractive over the next decade.

Another way to bring costs down would be to find ways to tap into other renewable energy sources that are more cost-effective than PV (e.g. through community ownership of energy facilities such as wind farms). Precinct development strategies may facilitate community ownership of energy facilities as they bring about an increased capacity to coordinate and deliver distributed renewable energy and micro-generation technologies. Additionally, district-wide systems may help to drive down costs as they benefit from efficiencies gained through collective management of energy, water, waste and transport. Several key challenges exist however for effective implementation of precinct development strategies including current inadequate financial, planning and property management models (Newton, Murray, Wakefield, Murphy & Khor, 2011). Research into what regulatory or voluntary schemes may enable energy systems to be effectively shared would be valuable.

Initiatives that may help to increase the cost effectiveness of low and zero carbon homes are discussed in Section 5.3.

4.3 Consumer Awareness of zero carbon homes

The second factor contributing to low consumer demand is that consumer awareness of the benefits of low and zero carbon homes appears to be low. There is very little readily available research that specifically looks at consumer awareness of, and demand for, low or zero carbon homes. However, our interview participants indicated that most consumers have little knowledge about how much it will cost to operate their home over

time and the benefits that low or zero carbon homes can deliver.

There are several reasons for low consumer awareness. First, there are numerous rating tools and multiple ways of describing and defining environmental performance and sustainability. This diversity and complexity makes consumer education difficult, as there are many competing messages.

Second, while some developers promote these homes, most do not. Most of the mass-market builders are doing little to promote more energy efficient homes and continuing to deliver homes that barely achieve the minimum energy performance standards. Consumers that are only exposed to these builders may never become aware of alternative design options that are available to them.

Third, while energy prices are rising, the cost of energy remains a relatively small proportion of the total household budget for many consumers. As such, few consumers are driven to find out more about how they can reduce their energy costs. As energy prices are likely to continue to rise into the future, this situation should change over time and lead to growing consumer demand for options to reduce energy costs.

Fourth, information on the cost of energy-using practices is poor. Energy bills often arrive months after the energy was used, providing little opportunity to become familiar with the costs of specific practices. Most energy bills do not provide information on how a household's energy use compares with others, so households may not have a sense that they are paying more for energy than others. Smart meters and energy bill benchmarking may have a role to play in increasing awareness of the cost of energy-using practices.

Increased consumer awareness of the benefits of zero carbon homes for reducing energy costs, improving resale value, improving comfort and improving standard of living is crucial. Ideas for community education and marketing are discussed in Section 5.5.

4.4 Building industry capacity

Whilst the capacity of the building industry to deliver low and zero carbon homes is increasing, our interview participants were unanimous in the opinion that the building industry currently lacks the skills and capability to deliver zero carbon homes on a large scale. Some participants were scathing about the persistence of old-fashioned construction techniques and the inability of many builders to deliver well-sealed and appropriately insulated homes. Clearly, capacity building for the building industry needs to be a key area of focus for ASBEC and its members, building on existing schemes like the Clean Energy and Other Skills Package.

Whilst industry skills are lacking on a large scale, at the higher end of the market industry skills are developing, with market leaders continuing to push the boundaries and delivering 8 and 9 star NatHERS homes. Some interviewees identified demonstration homes as an effective way of sharing industry knowledge and for driving a shift in industry capacity. Programs such as the Victorian Master Builders Association Green Program, which provides training on how to provide energy efficient homes cost effectively, were also praised for increasing industry capacity. It was noted that, whilst the vast majority of those participating in the Victorian Master Builders Association's Green Program are market leaders in sustainability, there has been a growing interest and participation rate of new builders in the program. A major factor driving new builders towards the program is the encouragement being given by the Victorian Building Commission to new builders to participate in the program as a way of differentiating themselves in the market and gaining leading edge skills.

Some interviewees identified 7 star NatHERS homes as completely achievable and cost effective with existing tools and techniques. However, these interviewees believed that there would be significant resistance from industry if there was a move to regulate 7 star NatHERS, due largely to the initial costs in changing building processes and the conservative nature of the industry. As noted earlier, there are also variations in accepted practice between markets that make higher standards easier to achieve in some parts of Australia. Several interview participants raised the Perth market, where double brick homes are the norm, as an example of this.

Some of the reasons brought up by interview participants for the lack of industry capacity to deliver zero carbon homes included:

- At this point in time, anything more than the minimum requirement is not something the mainstream homebuyer is particularly interested in. Most builders develop sufficient skills to meet this mainstream demand, not to change it.
- Insufficient monitoring and compliance mechanisms are in place to ensure buildings are built as designed. A home may achieve a 6-star rating in simulation but fall short of that performance in practice because of poor building sealing and poor installation of insulation. As few audits are conducted, builders are not learning to improve their practices over time.
- There are additional costs for energy efficient materials themselves (such as double glazing & high level insulation) and additional costs associated with using such materials (for example the increased time in sourcing new materials and learning how to use them). As many interviewees noted, the construction industry on a whole is a conservative industry and is happy to continue working with materials and techniques they know work. In a highly competitive industry, few builders have the time to experiment with new materials and techniques.

An additional issue to note is that most of the existing industry capacity in delivering low or zero carbon homes is focused on new detached houses. There are few, if any, examples of multi-residential buildings that approach a zero carbon standard in Australia. There are also relatively few examples of retrofits that approach a zero carbon standard. Given that urban planning is increasingly focused on increasing the density of our cities, there is likely to be stronger demand for both renovations and multi-unit residential buildings in the future. It is critical for the building industry to develop skills in meeting this demand more sustainably.

Research conducted by the Australian Housing and Urban Research Institute argues that high-density precincts and redirecting growth and urban investment inwards, rather than outwards, represents a more sustainable form of urban development from economic, environmental and social perspectives (Newton, Murray, Wakefield, Murphy & Khor, 2011). Consumer demand is supporting this change in direction. From a survey of over 1200 households, 58% of the sample identified ‘compact city’ as their preferred living environment (Newton, Murray, Wakefield, Murphy & Khor, 2011). However, a recent article published in The Fifth Estate (“High rises apartments can be greened, it takes a little energy,” 2011), argues that high-rise apartments are typically more energy intensive than detached houses, using up to 30 per cent more energy. Lighting in common areas, lift motors and water pumps were identified as the main contributors to the increased energy use. Finding ways to build and retrofit low and zero carbon high-rise developments is vital in light of their increased energy use and the likely increase in this kind of development over time.

5 A ROADMAP FOR ZERO CARBON HOMES IN AUSTRALIA

A comprehensive roadmap for zero carbon homes in Australia is beyond the scope of this report. However, we can provide a foundation for further work on such a roadmap by identifying key strategies that ASBEC and its members could pursue to facilitate the emergence of zero carbon homes by 2020. Strategies are grouped into the following categories:

- Advocacy (Section 5.1)
- Building industry skills and capability (Section 5.2)
- Financing and cost-effectiveness (Section 5.3)
- Supporting voluntary action (Section 5.4)
- Marketing (Section 5.5)
- Research and technical support (Section 5.6)
- Alliances and collaboration (Section 5.7).

These strategies are elements of a roadmap but would need to be prioritised, sequenced and developed in more detail to make up a full roadmap.

5.1 Advocacy

While some of our interview participants expressed a preference for voluntary initiatives over regulation, others saw a role for regulation in delivering zero carbon homes and some saw it as critical. ASBEC and its members have opportunities to influence government policy and regulation through advocacy. Recommended strategies include:

- Advocate for inclusion of a target for all new homes to be zero carbon by 2025 in the National Buildings Framework, with interim targets for 2015 and 2020 and additional targets for home renovations. Establishment of a long-term regulatory target will provide the building industry with greater certainty and support innovation to reduce the cost of delivering zero carbon homes. Targets should be implemented through amendments to the Building Code of Australia (for thermal performance and fixed appliances), with additional policies and incentives to move towards zero carbon for plug in appliances.
- Plan ongoing work programs to take advantage of review points established in the National Buildings Framework, once it is released.
- Strengthen requirements in the BCA relating to building sealing to reduce air infiltration and leakage.
- Advocate for nationally consistent implementation of energy and carbon targets established in the BCA (i.e. harmonise requirements across jurisdictions).
- Support mandatory disclosure of energy and greenhouse performance but advocate for a more complete rating of sustainability performance and for national consistency in implementation.
- Seek government and industry support for development of a new national home sustainability rating tool. The rating tool should provide a single, consistent approach for use in mandatory disclosure and assessment of performance against BCA requirements and voluntary standards. The rating tool should include a full set of ratings at release that covers the various zero carbon definitions (i.e. base building, occupied, life cycle etc.) and positive energy homes. While the rating tool may be based on modelled performance, it should be supported by a comprehensive performance-monitoring program to identify ongoing opportunities for improvement in the models and in practices. The tool should cover energy, greenhouse and water performance, allowing a broader strategic approach focusing on zero impact homes, rather than just zero carbon homes.
- Advocate for a comprehensive training, certification and compliance auditing program to support the new rating tool. Auditing of homes to check whether they are constructed to the standard they were modelled at under NatHERS is limited at present and interviewees indicated that many homes would

not achieve the modelled energy performance in practice. Whether or not there is a new rating tool, an audit program is essential. In addition to audits, the compliance program could include innovative on-the-job and industry-relevant training approaches, with an educational and motivational purpose rather than a compliance purpose. Avenues are also needed for auditors and industry to provide feedback on how rating schemes are operating in practice.

- Support the development of a National Energy Savings Initiative (ESI) and advocate for it to include specific measures to support emergence of zero carbon homes, such as generation of bonus energy efficiency certificates for homes that achieve a verified zero carbon standard (based on monitoring of actual performance).
- Advocate for some of the funding for the Low Income Energy Efficiency Program (LIEEP) under the Clean Energy Future Package to be allocated to delivery of zero carbon homes, as well as available funding under this scheme related to retrofitting. An application could also be made for funding under the Household Energy and Financial Sustainability Scheme.
- Improve lot layout and solar access rules to support good passive solar house design. There is a measure in the NSEE on this but our interview participants argue more needs to be done in this area.

5.2 Building industry skills and capability

Section 4.4 discussed the lack of industry capacity to deliver low and zero carbon homes on a large scale. The following initiatives are recommended to build industry skills and capability:

- Develop a zero carbon home web portal, or build on existing websites such as Your Home and Living Greener, with information for builders and consumers on zero carbon homes, including definitions, the benefits of zero carbon homes and a database of useful building products, techniques and suppliers for building zero carbon homes in various climate zones. An accreditation process or other quality assurance process may be valuable to create and maintain confidence in the products and services promoted on the site.
- Collect Australian case studies of zero carbon homes in different climate zones and markets and publicise through the web portal. The case studies will have the twin benefit of providing information to the industry on how to achieve zero carbon homes and promoting and supporting early movers.
- Work with organisations such as the Department of Education, Employment and Workplace Relations, Skills Australia and the Construction and Property Services Industry Skills Council to ensure that skills, education and training initiatives like the Clean Energy and Other Skills Package meet the needs of the building industry. For example, innovative on-site training programs that teach energy efficiency skills on the job may have greater impact for builders than classroom training. Training programs need to cover the full range of professions involved in delivery of homes, including planners, designers, builders and building-related trades.
- Seek funding from the National Workforce Development Fund to develop and deliver specific building industry skills training on energy efficiency and zero carbon homes
- Assist with the development of new training and accreditation programs for building raters to support the introduction of a new national home sustainability rating tool and new mandatory and voluntary standards.
- Establish an annual awards program or competition to recognise projects or organisations that lead the way in delivering cost-effective zero carbon homes
- Support the collection of data needed for strategic urban redevelopment, including data on property, planning, infrastructure and demographics. This needs to be brought together into shared urban spatial information systems to enable exploration of development opportunities and regeneration sites by property developers, design and construction professionals, investment organisations, local government bodies and neighbourhood communities. In 2011, projects to develop information platforms will begin at the Australian Urban Research Information Network (AURIN) and the CRC for Spatial Information (Newton, Murray, Wakefield, Murphy & Khor, 2011).

5.3 Financing and cost-effectiveness

To improve the affordability of low and zero carbon homes the following initiatives are recommended:

- Develop and regularly update the business case for zero carbon homes as a basis for advocacy to government. Interview participants indicate that governments will not move to require zero carbon homes unless cost-benefit analysis indicates that there is a community benefit in doing so.
- Prioritise actions to achieve low and zero carbon homes in a way that minimises costs over the long term if steps are taken incrementally to achieve the standard. Requiring homes to maximise passive solar design first will minimise the need for specialised building products and will minimise costs down the track to improve the performance of the home.
- Advocate for provision of cash rebates to builders for use of selected low carbon building materials and products, such as double-glazing, insulation or low-e glass, that have the potential for a large mainstream impact. Initial rebates can help to drive demand, build economies of scale and drive down costs over time. Mechanisms to explore how these discounts could be passed on to consumers should be considered.
- Work with financial institutions to develop innovative financing mechanisms to ease the up-front cost of energy efficiency and renewable energy improvements. For example, Pay As You Save schemes provide loans for carbon reduction measures that remove the upfront cost. Repayments are made from energy bill savings and arrangements can be made to link the loan to the home so that occupants do not keep paying once they move out. Governments may also provide support to offer the loans at reduced interest rates. Of course, efforts will need to be made to gain consumer confidence in such programs given the failings of the past Green Loans and home insulation programs.
- Support the development of environmental upgrade agreements as a way of financing retrofits of existing multi-residential buildings. These schemes have already been introduced in NSW and the City of Melbourne (as part of the 1,200 Buildings Program). They allow for the cost of retrofits to be recouped through increases in Council rates, which avoids the split incentive that exists in rental properties.
- Fast track planning processes, conditional on achieving zero carbon housing.
- Advocate for favourable tax treatment for zero carbon homes, such as stamp duty concessions for zero carbon homes and tax deductions for renovations that achieve particular energy efficiency standards.

5.4 Support for voluntary action

Canada and the UK are among the leaders in delivery of zero carbon homes, and both countries use a mix of voluntary and mandatory standards to encourage the emergence of such homes. Voluntary standards clearly have a role to play in rewarding market leaders and building consumer awareness of low and zero carbon options. However, it is critical that voluntary standards are aligned with any mandatory requirements.

We recommend that ASBEC and its members work with appropriate partners to establish a voluntary standard for zero carbon homes that builds on mandatory requirements as they emerge. The ideal to work towards is that the voluntary standard will use the same assessment system used for mandatory disclosure of sustainability performance and for assessment of compliance with the BCA. Voluntary standards recognise performance at the high end of the rating scale, inspiring developers and builders to go beyond minimum regulated performance.

The voluntary standard should include a certification process, regular audits of compliance and a suitable logo that certified homes can display to build consumer awareness and recognition.

5.5 Marketing

As cost-effectiveness begins to improve, and low and zero carbon homes start to generate an increase in resale value, marketing zero carbon homes will become increasingly important. The following initiatives are recommended:

- Consolidate existing market research on consumer demand for low and zero carbon homes and conduct new research to develop a more comprehensive picture of the barriers to consumer acceptance of zero carbon homes in different markets. This research may allow identification of niches where zero carbon homes are closest to widespread acceptance, opening up opportunities to develop technologies and practices in those niches before mainstream adoption.
- Support initiatives that give consumers better feedback on their electricity use, such as smart metering with real-time feedback and energy bill benchmarking.
- As part of the zero carbon home web portal(s) discussed in Section 5.2, develop consumer-focused materials on the benefits of zero carbon homes. Emphasise financial benefits (in the context of rising energy prices) and provide evidence for comfort benefits, health benefits and increases in standard of living in these and other marketing materials.
- Support the development of user manuals and home orientation training for new occupants of zero carbon homes so that consumers learn to maximise the benefits of these homes.
- Work with media partners to develop programs to provide consumers with simple information, ideas and plans for building or renovating zero carbon homes. These programs could range from a reality television program to deliver zero carbon homes to a newspaper supplement providing readers with plans to build their own zero carbon home to one page fact sheets that people can give to designers.
- Maximise media exposure for other initiatives discussed above, such as the awards program for leading zero carbon homes.
- Ensure that the voluntary standard discussed above establishes a recognisable brand and logo that will become familiar over time.
- Build on existing open house day programs, such as Sustainable House Day.
- Provide information to consumers on what it would take to increase the energy efficiency performance of their house, e.g., provide a report with recommendations for achieving higher levels. ASBEC and its members could advocate to have this required through the BCA, similar to the UK approach, discussed in Section 3.3.2.
- Give consumers information that is easy to understand quickly and that has value to them, e.g., $savings/m^2 or per home.
- Ensure effective recognition of people and organisations who deliver zero carbon products and services so people who become interested to learn more know exactly who to go for and where to find these people. Such information could be included in the zero carbon home web portal(s) discussed above.
- Facilitate public awareness of passive solar building methods. Most people don't understand that they can have a much more comfortable and efficient house if well oriented and choosing a house that suits their block.
- Support efficient operation of low and zero carbon homes. A typical family doesn't care that much about energy efficiency and thus may not operate the building efficiently as designed. Given this, an option may be to design out the need for occupant intervention but with options for consumer education (for those who are interested).

5.6 Research and technical support

Many of the initiatives identified here will require ongoing research and technical support. The Zero Carbon Hub in the UK is a useful model for provision of ongoing research and technical support to overcome barriers to zero carbon homes. Some research initiatives have already been mentioned above. Additional

recommended initiatives include:

- Build a database on energy and carbon performance of zero carbon homes and the additional costs to achieve that performance.
- Support research comparing as-built energy performance to rated energy performance. This will help to identify opportunities to improve both rating tools and building practices. There may be opportunities to collaborate with the Commonwealth Government's existing Energy Efficiency Data Project.
- Develop an industry-endorsed definition of zero carbon homes, building on the work already undertaken on definitions (Riedy, Lederwasch & Ison, 2011)
- Collaborate with the CSIRO, or other interested organisations, on development of a home design tool for zero carbon homes that will help builders and consumers to make decisions about the most cost-effective features to include in a design to achieve zero emissions.
- Develop a technology roadmap to support the development of technologies that are critical to the mainstream delivery of zero carbon homes.
- Support occasional research on technical issues where these are critical to the further development of zero carbon homes, such as alternative construction techniques like reverse brick veneer or automation methods to reduce reliance on occupant behaviour.
- Support research into how to enable the electricity grid to handle increasingly decentralised and time-variable electricity generation from buildings.
- Support research into the technologies and practices available to achieve zero carbon standards in multi-residential buildings and in renovations of existing buildings, as these areas are falling behind new detached homes in delivery of zero carbon homes.

5.7 Alliances and collaboration

Almost all of the initiatives recommended above require a collaborative approach and financial support. ASBEC should seek to collaborate with organisations outside its current membership, potentially take on a facilitation role or alternatively strategically partner with other organisations as needed for particular projects.

As noted earlier, the Canadian Zero Energy Home Coalition and its recent Implementation Plan provides a great example of what is needed here. ASBEC is well placed to take a similar role to the Canadian Zero Energy Home Coalition. In highlighting the importance of collaboration the Implementation Plan identifies that:

There are many players that are part of building a Net-Zero Energy Home (NZEH). There are the architects and engineers, the industry professionals who assist with the modelling/simulation optimization and performance testing, the product manufacturers and suppliers, the trades, the developers, the municipalities, the utilities, the industry associations, academia, the R&D networks, the realtors, and of course, there are the builders. And perhaps most importantly, there are the home buyers. In order to ensure that more NZEHs are built, all stakeholders must be engaged (Winkelmann 2011, p.4).

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