AUSTRALIAN SUSTAINABLE BUILT ENVIRONMENT COUNCIL

DEFINING ZERO EMISSION BUILDINGS

REVIEW AND RECOMMENDATIONS: FINAL REPORT

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

Authors: Chris Riedy, Aleta Lederwasch and Nicky Ison

PRESIDENT'S FOREWORD

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, Sustainability Victoria and Property Council of Australia. The report has been made possible with funding from task group members in particular Sustainability Victoria.

The Zero Emissions Residential Task Group was formed to build upon and contribute to ASBEC's body of knowledge and its important advocacy role. After discussions with the Commonwealth Government in 2009 and with support from the then federal Department of Environment, Water, Heritage and the Arts, ASBEC undertook to engage with industry to discuss a national agenda for reducing energy emissions in the residential sector, at least cost to the economy. As a result of that meeting, ASBEC established the Zero Emissions Residential Task Group, to draw upon the wealth of experience from within its existing membership.

Globally, buildings account for more than 40 precent of primary energy use and 24 per cent of greenhouse gas emissions (IEA SHC & ECBCS 2010). Zero emissions buildings are an attempt to reduce this impact and many such buildings have now been developed around the world. However, most of these buildings have been experiments or demonstration projects and their diversity means that there is no internationally agreed terminology or definition for zero energy or zero emission buildings (Marszal) et al. 2011).

This report has been prepared to reach common ground on a suitable definition for zero carbon buildings providing a baseline with consistent language to assist stakeholders to progress Australian homes towards zero emissions. The standard definition recommended in this report, outlined below, applies to building emissions and provides a starting point for possible voluntary and governance initiatives to deliver zero carbon buildings, noting the likelihood that some developers, builders and home owners will want to push further as market and regulatory initiatives evolve over time.

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***
- ***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 CO2e/m2/yr.***

ASBEC acknowledges the expertise and efforts of the University of Technology Sydney's Institute for Sustainable Futures in the preparation of this report, which is important research and will provide much needed guidance in this area.

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, Mr Mark Allan, ph. 03 9656 5007 or marka@blp.com.au or the Executive Officer of ASBEC, Ms Jayne Paramor ph. 02 8252 6707 or jayne@asbec.asn.au.

Tom Roper
President, ASBEC

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The Zero Emissions Residential Task Group of the Australian Sustainable Built Environment Council initiated this project. ISF would like to thank all the members of ASBEC for supporting this project, and particularly the Task Group members and the Task Group Chair, Mark Allan.

Many people gave up their time to speak with ISF during the project and provide their insights into zero emission buildings, including Andrew Aitken (Green Building Council Australia), Ché Wall (Bovis Lend Lease), Greg Foliente (CSIRO), Craig Daniel (Land Management Corporation, South Australia), Yma ten Hoedt (Office of Environment and Heritage, NSW), Gordon McAllister (Department of Climate Change and Energy Efficiency), David Waldren (Grocon), Anna Surgenor (UK Green Buildings Council), Karsten Voss (BergischeUniversität Wuppertal) and Clive Turner (Zero Carbon Hub). We sincerely appreciate their time and their willingness to share their thoughts.

Finally ISF would like to thank Caitlin McGee and Steve Harris from the Institute for Sustainable Futures for their contributions to this report.

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DISCLAIMER

EXECUTIVE SUMMARY

Background

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

- Review existing definitions used for low, zero and positive impact buildings
- Recommend a suitable definition that could be used in Australia to support consistent communication about low impact buildings and potentially as a basis for future building regulation or voluntary initiatives.

We reviewed academic literature and drew out definitions from diverse international programs that aim to deliver low impact buildings. We also interviewed key stakeholders in Australia and internationally. We then analysed the variation in existing definitions and made recommendations on suitable definitions for the Australian context.

State of play for low impact buildings

Globally, buildings account for more than 40% of primary energy use and 24% of greenhouse gas emissions (IEA SHC & ECBCS 2010). Zero emission buildings are an attempt to reduce this impact and many such buildings have now been developed around the world. However, most of these buildings have been experiments or demonstrations and their diversity means that there is no internationally agreed terminology or definition for zero energy or zero emission buildings (Marszal et al. 2011).

Some of the many terms in common use include: near-zero energy; zero energy; zero net energy; passive house; energy plus; fossil fuel free; 100% renewable; zero carbon; net zero carbon; carbon neutral; climate neutral; climate positive; and positive development. Differences in terminology and definitions are potentially confusing and pose problems for communicating about low or zero impact buildings. However, with the emergence of substantial regulatory programs to deliver zero emission buildings, such as the European Directive on the Energy Performance on Buildings and the UK Code for Sustainable Homes, there is now increased attention to standardisation of definitions. The International Energy Agency (IEA) has established a specific project to 'develop a common understanding of a harmonised international definitions framework' (Voss et al. 2009; IEA 2010).

Based on the IEA and other work, we have identified the following as the key points of difference between definitions:

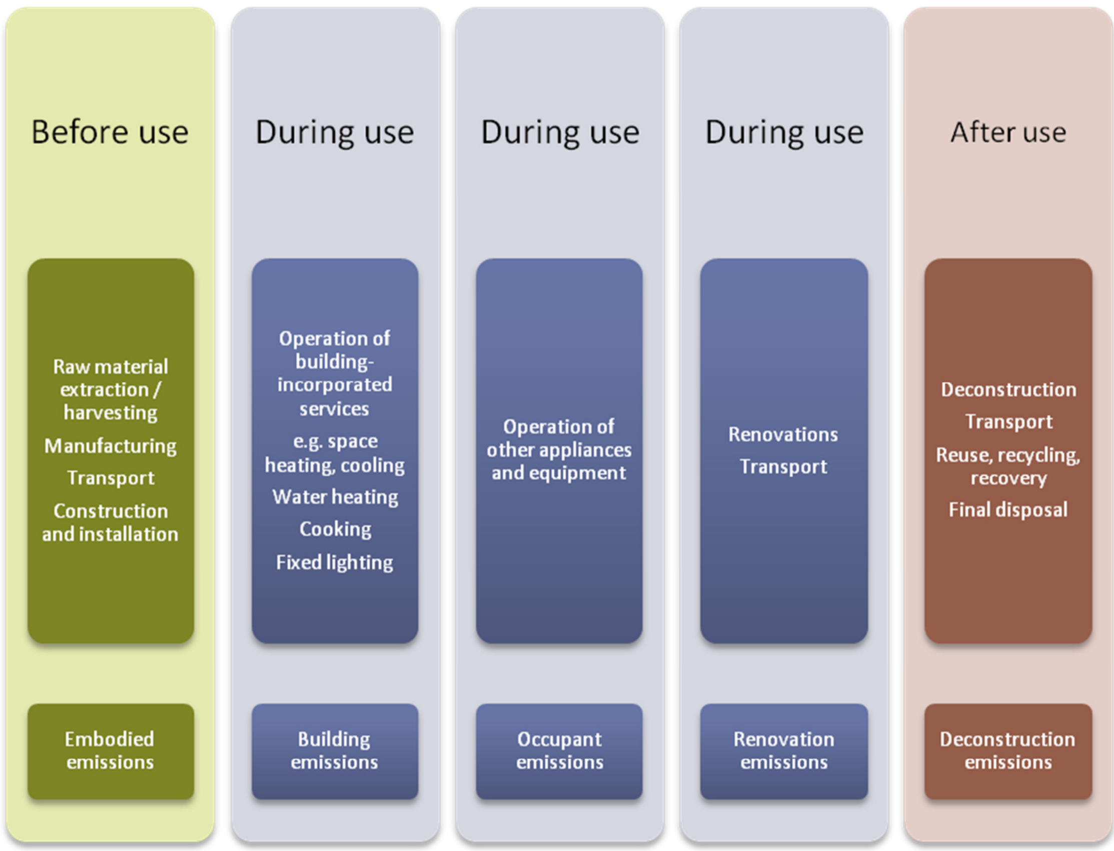
- Life cycle boundary – which parts of a building life cycle are included and excluded?
- Assessment methods and metrics (e.g. primary energy or greenhouse gas emissions)
- Timeframe – over what timeframe is the building impact assessed?
- Grid connection – does the definition place any conditions on grid connection?
- Sectoral differences – are there differences between residential and non-residential definitions?
- Building type – how are different building types treated?
- Spatial boundary – does the definition focus on the building, neighbourhood, city or regional scale?
- Allowable emission reduction options – does the definition place limits on allowable ways of reducing energy use or greenhouse gas emissions?
- Conditional requirements – does the definition set other conditions, e.g. energy efficiency or thermal comfort standards?

Analysis of definitions

Life cycle boundary

Buildings are responsible for emissions before use (embodied emissions), during use (from use of building-incorporated services and appliances, and maintenance and refurbishment) and after use. Figure ES1 provides a conceptual breakdown of the building life cycle. Perhaps the biggest source of variation between the definitions we have reviewed stems from different decisions about where to draw the boundary within the building life cycle. In theory, a zero carbon building should achieve zero emissions over the full life cycle. In practice, many definitions only include emissions from building-incorporated services (e.g. space heating and cooling and water heating),as these are easiest to model and are considered an appropriate target for regulation. Nevertheless, some definitions and some developers do go further.

Figure ES1: Conceptual breakdown of building life cycle. Adapted from the United Nations Environment Programme's Common Carbon Metric (UNEP SBCI 2010)**.**



We recommend the use of a hierarchy of standard terms in definitions to represent the parts of the building life cycle that are covered. Figure ES1 provides one logical basis for such a hierarchy:

- Zero carbon building, which includes the 'building emissions' shown in Figure ES1
- Zero carbon occupied building, which includes the 'building emissions' and 'occupant emissions'
- Zero carbon embodied, occupied building, which includes the 'embodied emissions', 'building emissions' and 'occupant emissions'
- Zero carbon life-cycle, which includes all emissions shown in Figure ES1.

We recommend use of the zero carbon building definition above as the starting point for new regulatory and voluntary initiatives. Definitions that go further could use the terminology above, for consistency and comparability. This recommended terminology has a logical basis (in Figure ES1) but should be understood as tentative. It needs to be tested against various use scenarios; such testing is outside the scope of this study.

We recognise that these terms are not particularly user-friendly – it is difficult to adequately cover the complexity and range of options across the building life-cycle in a simple way. One way to simplify the terms would be to assign classes or types to each category, e.g. a Class 1 zero carbon building would cover building emissions, a Class 2 zero carbon building would cover building and occupant emissions etc. Further work, beyond the scope of this report, would be required to develop a suitable classification scheme.

Further work is also needed to define the precise end-uses included in each definition. For example, cooking emissions could be defined as occupant emissions instead of building emissions. Further, the lists of end uses in Figure ES1 are intended as examples and are not exhaustive. Building emissions could also include ventilation, swimming pool heating, swimming pool pumps and lifts in apartments (for example).

Assessment methods and metrics

Much of the variation in existing definitions reflects the use of different indicators of impact and different calculation methods. Definitions may use delivered energy, primary energy, greenhouse gas emissions, energy costs or exergy as the metric for assessing impact. The most common practice is to use primary energy as the metric, often because the regulatory focus in building codes has been on regulation of energy use.

We recommend use of Scope 1 and 2greenhouse gas emissions[1] as the preferred metric for a definition, reflecting a higher priority on climate change response than energy security. Using greenhouse gas emissions allows for full accounting for emission reduction options of different kinds and is consistent with existing Australian building rating tools. Focusing on Scope 1 and 2 emissions ensures consistency with the National Greenhouse and Energy Reporting System and other prominent initiatives. Our preferred terminology is zero carbon, for simplicity. An appropriate metric would be carbon intensity in kg CO_2-e/m^2/yr and the metric should be absolute, rather than a reduction from a benchmark.

Assessment methods depend very much on the application. Both modelling of expected performance and monitoring of actual performance are likely to have a role to play in assessing compliance with zero carbon definitions. New modelling approaches or assumptions will be needed to cover the full range of building emissions, as NatHERS only covers the building fabric.

Timeframe

Definitions need to establish a timeframe for achieving zero impact. The timeframe is closely linked to the choice of life cycle boundary. Definitions that cover the full life cycle of a building need to achieve zero impact over the entire building life, or may assume a building lifetime (typically 50 years). Most definitions, which focus on operational emissions, require achievement of zero impact on an annual basis. A few definitions require zero impact on a seasonal or monthly basis to reduce demand on the electricity grid. We recommend a definition that assesses impact on an annual basis for feasibility and consistency with other approaches.

[1] Scope 1 and 2 emissions are those resulting from direct fuel combustion (e.g. burning natural gas) and electricity use. Further details can be found in the glossary.

Grid connection

Most definitions allow for buildings to be grid connected and achieve net zero impact, rather than requiring zero site impact. While this is generally the most cost-effective solution and makes good use of existing resources, it does have the potential to create grid management issues and support the use of electricity generated from fossil fuels. Our recommendation is that grid connection should be allowed (but not required) in Australian definitions of zero carbon buildings. Developers who wish to go further and remove any grid connection could distinguish these buildings by calling them zero carbon autonomous buildings. If there is a large rollout of grid-connected zero carbon buildings in the future, further analysis of the implications for electricity network infrastructure would be recommended.

Sectoral differences

The definitions proposed in this report are intended to apply across sectors (residential, commercial, industrial, mixed use), while noting that there will be differences in implementation across sectors. These differences primarily relate to the specific building-incorporated services included in the building definition, modelling and assessment methods used in different sectors (e.g. different rating tools) and the feasibility of particular emission reduction options.

Building type

Appreciating that the ultimate purpose of implementing a zero carbon definition is to reduce the environmental impact of the total building sector it is important and valuable to ensure that existing buildings and the full range of dwelling types are covered in any definition of zero emission buildings. The definitions proposed in this report are intended to cover all residential building types (new, existing, detached, semi-detached and low and high-rise apartments) and non-residential building types (e.g. offices, industrial, hospitals, schools and universities, shopping centres), while recognising that it will not be practical to require all of these building types to achieve a zero carbon definition in the short-term. Different standards should be required of new and existing buildings, and of different building types, reflecting the different opportunities and challenges faced by each in being energy efficient and generating renewable energy on-site.

Spatial boundary

There are diverse potential scales or spatial boundaries that a zero carbon definition can be applied to. In this research, scales examined include detached homes, residential buildings, all buildings, precinct or city scale. Precinct, community and city-scale initiatives to achieve zero carbon are valuable and can exist alongside building-scale approaches. However, the focus of this project is on developing a building-scale definition. Scaling up the building-scale definition proposed here to other scales is possible but may require attention to new emission sources that are introduced as the spatial scale increases.

Emission reduction options

Many initiatives to deliver low impact buildings qualify the definitions they use by placing constraints on allowable emission reduction options. ISF recommends that voluntary and regulatory initiatives allow energy efficiency, on-site clean energy solutions and off-site clean energy solutions. However, specific targets or standards should be established for energy efficiency and on-site clean energy to ensure that these options are given priority over off-site solutions. The cost-effectiveness and technical feasibility of available emission reduction options will be an important consideration in setting these standards, particularly for upgrading existing building stock.

Allowable off-site emission reduction options should deliver clean energy that is additional to other regulatory schemes supporting clean energy. One possible approach is to put in place a Community Infrastructure Levy to support development of community-scale energy facilities, perhaps administered by local government. This kind of approach could provide a guarantee that off-site solutions are additional to existing schemes and are reliable over time, while also realising ancillary benefits associated with local empowerment, ownership and control.

Conditional requirements

Many definitions include conditional requirements that must be met to deliver a zero impact building. These may relate to energy efficiency, allowable emission reduction options, comfort standards, efficiency of appliances and equipment, cost limits and sub-metering. We recommend adoption of conditional requirements for energy efficiency and emission reduction options in the standard definition of a zero carbon building, as discussed above. Other conditional requirements could be added as appropriate for particular initiatives.

Summary of recommendations

We recommend the following standard definition for zero carbon buildings:

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*
- *Zero carbon buildings must meet specified standards for energy efficiency and on-site generation*
- *Compliance is based on modelling and/or monitoring of greenhouse gas emissions in kg CO_2-e/m^2/yr.*

Recognising that there is no 'one-size-fits-all' definition, we also propose consistent terminology for variations on this definition, as outlined in Table ES1.

Table ES1: Proposed variations in terminology.

Standard definition	Zero carbon building
Include occupant emissions	Zero carbon occupied building
Include embodied emissions	Zero carbon embodied building
Include all emission sources in the building life cycle	Zero carbon life-cycle building
No grid connection	Autonomous zero carbon building
Achieves less than zero emissions	Carbon positive building (or carbon positive occupied building etc)

The standard definition is suitable for use in regulatory and voluntary initiatives but simpler language may be appropriate to communicate the definition to the marketplace. Some possible market-friendly language is as follows:

> *If operated as designed, the only greenhouse gas emissions from this home will be from the appliances and equipment that you bring with you when you move in. There will be no emissions from running the built-in heating and cooling, water heating, lights, stovetop and oven.*

The list of appliances in the second sentence could be modified based on final decisions on which end uses to include in definitions for specific initiatives.

TABLE OF CONTENTS

Glossary

ACCC	Australian Competition and Consumer Commission
ASBEC	Australian Sustainable Built Environment Council
Autonomous building	A building that meets its energy needs without any connection to the electricity grid
Building emissions	Emissions associated with the operation of building-incorporated services, such as space heating and cooling, water heating and fixed lighting
CBD	Commercial Building Disclosure scheme – an Australian Government initiative requiring disclosure of the energy efficiency of a building at the point of sale or lease
Deconstruction emissions	Emissions associated with the demolition of a building and reuse, recycling or disposal of its materials
Embodied carbon (or embodied emissions)	Embodied carbon is the greenhouse gas emissions generated in producing a material and transporting it to the building site
Embodied energy	Embodied energy is the energy used to produce a material and transport it to the building site
IEA	International Energy Agency
ISF	Institute for Sustainable Futures
Life-cycle emissions	The total emissions generated by a building across its life-cycle, including embodied emissions, building emissions, occupant emissions, renovation emissions and deconstruction emissions
Low impact building	A building with a much lower environmental impact than the typical building, often approaching (but not reaching) zero impact
NABERS	National Australian Built Environment Rating System
NatHERS	Nationwide House Energy Rating Scheme
NGERS	National Greenhouse and Energy Reporting System
Occupant emissions	Emissions associated with appliances and equipment brought into a building when it is occupied, such as fridges, home entertainment equipment and phone chargers
Positive impact building	A building that improves environmental amenity, based on a particular definition of environmental impact. For example, a building may generate more renewable energy than it uses, thereby helping to reduce emissions elsewhere and having an overall positive impact on climate change.
Renovation emissions	Emissions associated with renovation of a building, defined as substantial changes to the building that are likely to require the use of energy-using equipment from off-site and involvement of specialist building expertise

Scope 1 and 2 emissions	The World Business Council on Sustainable Development and World Resources Institute established a reporting standard for greenhouse gases in 2004 (WBCD & WRI 2004). The reporting standard has been widely adopted, including by the Australian Government's National Greenhouse and Energy Reporting System. The standard defines Scope 1 emissions as direct greenhouse gas emissions from sources owned or controlled by the occupant, such as emissions from burning natural gas in the home. Scope 2 emissions are those from generation of electricity used in the building. Scope 3 emissions are other indirect sources of emissions.
UNEP	United Nations Environment Programme
Zero impact building	A building that has no net environmental impact, based on a particular definition of environmental impact
ZERTG	Zero Emissions Residential Task Group

1 INTRODUCTION

1.1 Background

Buildings are a major energy consumer and source of greenhouse gas emissions, globally and in Australia. Around the world, many organisations are looking at ways to greatly reduce building energy use and emissions. In some countries, governments, industry associations or researchers have begun to look at ways to make zero energy or zero carbon buildings the norm. However, as the Australian Competition and Consumer Commission (ACCC) recently pointed out, there is no accepted definition of carbon neutrality and similar terms (ACCC 2011). Some of the diverse terms in current use include carbon neutral, zero energy, zero carbon, near zero-energy and energy positive buildings. Definitions of these terms vary across jurisdictions.

Sustainability Victoria commissioned the Institute for Sustainable Futures (ISF) to review existing definitions and recommend an appropriate definition to use for buildings in Australia. Sustainability Victoria commissioned the work on behalf of the Australian Sustainable Built Environment Council's (ASBEC's) Residential Zero Emissions Task Group (ZERTG). ZERTG is working to develop a framework and advocacy campaign that defines, measures and rates zero emission homes. Members of ZERTG include representatives from Think Brick, 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 Commonwealth Department of Climate Change and Energy Efficiency and the City of Melbourne.

The objectives of the project are to:

- Review existing definitions used for low, zero and positive impact buildings
- Recommend a suitable definition that could be used in Australia to support consistent communication about low impact buildings and potentially as a basis for future building regulation or voluntary initiatives.

Although ZERTG is focused on residential buildings, the scope of the project includes residential and non-residential buildings. It also covers definitions used at precinct and city scales.

1.2 Approach

Our approach comprised the following steps:

- A comprehensive literature review, covering academic literature, major regulatory programs and major voluntary initiatives focused on low impact buildings
- Interviews with stakeholders involved in the delivery of low impact buildings
- Identification of the main components of existing definitions and sources of variation across definitions
- Analysis and development of recommendations.

Key literature is referenced throughout this report and a bibliography is provided in Section 5. A more complete list of sources that informed our thinking is provided in Appendix A. Stakeholders interviewed during the project are listed in the Acknowledgements at the front of the report.

1.3 Report Structure

The report is structured as follows:

- Section 2 provides a brief overview of the state of play for low impact buildings, based on the literature review
- Section 3 analyses the sources of variation across different definitions and provides recommendations on appropriate definitions for Australia
- Section 4 summarises and integrates the recommendations
- Section 5 lists the references cited in the report.

2 Literature Review: State of Play for Low Impact Buildings

This section provides a brief overview of the current state of play for low impact buildings. It identifies the important points of difference between definitions of low impact buildings as a starting point for further analysis in Section 3.

Globally, buildings account for more than 40% of primary energy use and 24% of greenhouse gas emissions (IEA SHC & ECBCS 2010). Buildings are also substantial users of water, materials and land. Reducing the environmental impact of buildings is a high priority for tackling climate change and other sustainability challenges. Responding to this challenge, builders and regulators around the world have been experimenting with ways to deliver lower-impact buildings over recent decades.

'Low impact' buildings are those with much lower environmental impacts than conventional buildings. Using this broad definition as a starting point allows us to include a diverse range of definitions that are of interest for this project. Examples of low impact buildings are passive houses and near zero energy buildings.

More recently, interest has shifted from low impact buildings to zero impact or positive impact buildings. The emergence of the concept of zero impact buildings is an attempt to move beyond just making buildings 'less bad' towards a situation where they make no net negative contribution (Rovers, R & Rovers, V 2008), and perhaps even a net positive contribution. Impact can be measured based on energy use or greenhouse gas emissions or various other indicators, which, as we will see in Section 3.2, is a key source of definitional confusion. In this section we will refer briefly to various definitions before examining the differences in more detail in Section 3.

The International Energy Agency (IEA) maintains a database of more than 280 international zero energy buildings, stretching back to the early 1990s (Musall et al. 2010). About a quarter of the buildings are in Germany, with large numbers also in the United States, Canada and Austria. These buildings have often been developed by researchers or ecologically minded developers to demonstrate concepts or meet their personal ethical objectives. While the developers may share a motivation to reduce building energy use and greenhouse gas emissions, they have employed very different techniques, terminology and definitions to pursue these goals. As a result, there is no internationally agreed terminology or definition for zero energy or zero emission buildings (Marszal et al. 2011).

Some of the many terms in common use include: near-zero energy; zero energy; zero net energy; passive house; energy plus; fossil fuel free; 100% renewable; zero carbon; net zero carbon; carbon neutral; climate neutral; climate positive; and positive development. Table 1 summarises some of the more prominent terms and definitions. This list is not exhaustive but does illustrate some of the diversity in terminology and definitions.

Some of the terminology differences are regional; for example, the United States has tended to favour definitions focusing on energy rather than greenhouse gas emissions, possibly because energy policy is less contentious in the United States than climate policy. Others favour particular terminology because they see it as easier to communicate or because it aligns with existing regulatory approaches.

Differences in terminology and definitions are potentially confusing and pose problems for communicating about low or zero impact buildings. Recently, there has been a shift from fragmented individual approaches to low impact building towards large-scale voluntary and regulatory initiatives. With this shift has come greater attention to the parameters of different definitions and the emerging possibility of an agreed international definition.

Table 1: Diverse definitions of low or zero impact buildings.

Terminology	Definition (as stated)	Source	Region	Link
Passive house	A building for which thermal comfort can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions – without the need for additional recirculation of air	Passivhaus Standard (also NatHERS 10 star)	Originated in Germany, now international but mostly in Germany, Austria and Scandinavia	International Passive House Association (http://www.passivehouse-international.org/)
Zero emission house (ZEH)	A ZEH is a detached residential building that does not produce or release any CO2 or other greenhouse gases to the atmosphere as a direct or indirect result of the consumption and utilisation of energy in the house or on the site	Australian Zero Emission House Project	Australia	http://www.auszeh.org.au/
Zero net carbon	Powered and heated by a combination of on and off site renewable energy, using fossil fuels only as back up	One Planet Living	International	http://www.oneplanetliving.org
Zero net CO_2 emissions (also zero carbon, zero net carbon)	The annual dwelling CO2 emissions ($kgCO_2/m^2/year$) from space heating and cooling, water heating, ventilation and lighting, and those associated with appliances and cooking must be zero when calculated according to the methodology in the Standard Assessment Procedure	UK Code for Sustainable Homes	United Kingdom	http://www.communities.gov.uk/planningandbuilding/sustainability/codesustainablehomes/
Zero net emissions	100% reduction in base building emissions from those of a specified benchmark building	Green Star (also Zero Emission	Australia	http://www.gbca.org.au/green-star/

Terminology	Definition (as stated)	Source	Region	Link
		Neighbourhoods)		
Nearly zero-energy	A building that has a very high energy performance and the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby	European Directive on Energy Performance of Buildings	European Union	http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm
Zero energy home	100% reduction in net operational energy use compared to the HERS Reference Home	Residential Energy Services Network (US)	United States	http://www.resnet.us/
Net zero energy	A net-zero energy home is capable of producing, at minimum, an annual output of renewable energy that is equal to the total amount of its annual consumed/purchased energy from energy utilities	Net-Zero Energy Home Coalition (Canada) Similar terminology used by International Energy Agency	Canada OECD	http://www.netzeroenergyhome.ca/ http://www.iea-shc.org/task40/
Net zero site energy	Produces at least as much energy as it uses in a year, when accounted for at the site	Torcellini et al	National Renewable Energy Laboratory (US)	http://www.nrel.gov/docs/fy06osti/39833.pdf
Net zero source energy	Produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site.	Torcellini et al	National Renewable Energy Laboratory (US)	http://www.nrel.gov/docs/fy06osti/39833.pdf

Terminology	Definition (as stated)	Source	Region	Link
Net zero energy emissions	A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources	Torcellini et al	National Renewable Energy Laboratory (US)	http://www.nrel.gov/docs/fy06osti/39833.pdf
Carbon neutral	Zero net greenhouse gas emissions	The 2030 Challenge, Carbon Neutral Seattle National Carbon Offset Standard, Carbon Neutral Program	United States Australia	http://architecture2030.org/2030_challenge/the_2030_challenge http://www.climatechange.gov.au/government/initiatives/national-carbon-offset-standard.aspx
Climate positive	Reduce amount of on-site CO_2 emissions to below zero, i.e. generate more renewable energy than total net greenhouse gas emissions, recycle and export more water than used and reuse, reduce and recycle more waste than is generated	Clinton Climate Initiative, Barangaroo	International	http://www.clintonfoundation.org/what-we-do/clinton-climate-initiative/cities/climate-positive

Some of the leading regulatory initiatives include:

- The Australian Government's Commercial Building Disclosure scheme
- The European Directive on the Energy Performance of Buildings, which requires all new buildings to be 'nearly zero-energy buildings' by 31 December 2020
- The United Kingdom Code for Sustainable Homes, requiring all new homes to be carbon neutral by 2016
- The United Kingdom requirement that all new non-domestic buildings be zero carbon by 2019.

While not specifically aiming to deliver zero impact buildings, the Australian Government's Commercial Building Disclosure (CBD) scheme is an important regulatory initiative that aims to use the marketplace to drive improvements in the energy efficiency of commercial buildings. Sellers or lessors of office space of 2,000 square metres or more will be required to obtain and disclose an up-to-date energy efficiency rating from 1 November 2011. Further details on how energy efficiency is assessed are provided in Section 3.2.2.

With its goal of new carbon neutral homes by 2016 and new carbon neutral non-domestic buildings by 2019, the UK is arguably the global leader in regulating for zero emission buildings and thinking through the issues that need to be considered when putting a definition into practice. The various reports produced by the UK during its regulatory process (e.g. UK Green Building Council, 2008; DCLG UK, 2011; Zero Carbon Hub, 2011)

are a valuable resource for thinking about issues such as whether there should be different standards for different building types and climate zones, and whether standards should be achieved in aggregate or at the individual building level. An emerging conclusion is that site constraints and building type (e.g. solar shading, lack of roof space in apartment buildings) make it difficult for all buildings to achieve a single zero carbon standard, so different standards need to be established for different building types (Zero Carbon Hub 2011). In practice, this has meant allowing particular types of buildings to achieve more of their emission reductions off-site, due to constraints on what can be achieved on-site.

Several voluntary initiatives have reached a similar conclusion and focus on achieving carbon neutrality at a precinct, community or city scale, rather than at building scale. Prominent voluntary initiatives include:

- The 2030 Challenge, led by Architecture 2030[2], which sets a target for all new buildings to be carbon neutral by 2030
- The Clinton Climate Initiative and US Green Building Council's Climate Positive program, focused on reducing greenhouse gas emissions for major precinct-scale urban developments to less than zero
- Bioregional and WWF's One Planet Living initiative, seeking net zero carbon buildings at a community scale by 2020
- Canada's Net Zero Energy Home coalition
- Carbon Neutral Seattle.

Links to the websites of each of these initiatives are provided in Appendix A.

Recognising the value of greater definitional consistency across these and other initiatives, the International Energy Agency (IEA) has developed a specific project – *Towards Net Zero Energy Solar Buildings* – to 'develop a common understanding of a harmonised international definitions framework' (Voss et al. 2009; IEA 2010). The project will run through to 2013 and has already begun to highlight definitional differences and move towards common ground. Work published to date includes several reviews of the key differences between the commonly used definitions (Sartori et al. 2010b; Marszal et al. 2011; Voss, Musall & Lichtme 2011) and an

[2] Architecture 2030 is a non-profit, independent organization established to rapidly transform the US and global building sector from a major contributor of greenhouse gases to a central part of the solution to climate change, energy consumption and economic crises.

overview and analysis of strategies used to deliver zero energy buildings around the world (Musall et al. 2010). The latter finds that zero energy buildings typically have energy efficiency that is much higher than other buildings and use photovoltaic panels to generate power.

As part of the IEA and other work, there have been several attempts to identify the important elements that distinguish definitions as a basis for further discussion. For example, Rovers and Rovers (2008) argue for differentiating definitions according to the system they address (e.g. building, community, city or region), the resource involved (e.g. climate, carbon, CO_2, “emissions”, energy, fossil fuels or renewable energy) and the target they adopt (e.g. “neutral”, 100%, zero, “free” or autarkic). Sartori et al (2010) emphasise the core requirement that the amount of energy exported must be greater than or equal to the amount of energy imported, but also identify potential differences relating to boundary conditions, crediting systems, the details of the balance, the temporal energy match and monitoring procedures. More recently, Marszal et al. (2011) identified the following sources of difference between definitions:

(1) The metric of the balance
(2) The balancing period
(3) The type of energy use included in the balance
(4) The type of energy balance
(5) The accepted renewable energy supply options
(6) The connection to the energy infrastructure
(7) Other requirements relating to energy efficiency, the indoor climate and building–grid interaction.

Based on these and other sources, we have identified the following components of definitions of low impact buildings for further analysis:

- *Life cycle boundary* – which parts of a building life cycle are included and excluded from the definition? For example, does the definition only include operational energy use or does it also include embodied energy?
- *Assessment methods and metrics* – does the definition focus on energy or greenhouse gas emissions, for example? How is the impact calculated?
- *Timeframe* – over what timeframe is the building impact assessed?
- *Grid connection* – does the definition assume grid connection or place any conditions on grid connection?
- *Sectoral differences* – are definitions for residential buildings significantly different to those for commercial buildings?
- *Building type* – do definitional differences emerge based on building type, e.g. new vs. existing buildings, or apartments vs. houses?
- *Spatial boundary* – does the definition focus on the building, neighbourhood, city or regional scale?
- *Allowable emission reduction options* – does the definition place limits on allowable ways of reducing energy use or greenhouse gas emissions? For example, can credit be claimed for GreenPower, carbon offsets or other off-site emission reductions?
- *Conditional requirements* – does the definition set other conditions, e.g. energy efficiency or thermal comfort standards?

3 ANALYSIS OF DEFINITIONS

This section examines each of the points of difference between definitions identified at the end of Section 2 and proposes recommendations on how to resolve each point of difference for an Australian definition.

3.1 Life Cycle Boundary

Figure 1 depicts a typical building life cycle, showing the sources of emissions at each stage of the life cycle. This figure was developed by the United Nations Environment Programme (UNEP) as part of its project to establish a common carbon metric for buildings (UNEP SBCI 2010). As shown, buildings are responsible for emissions before use (embodied emissions), during use (from use of building-incorporated services and appliances, and maintenance and refurbishment) and after use. Perhaps the biggest source of variation between the definitions we have reviewed is due to different decisions about where to draw the boundary within the building life cycle. This section provides an outline and assessment of the choice of life cycle boundary.

Figure 2 provides a conceptual breakdown of the building cycle with our preferred terminology.

Figure 1: Sources of emissions over a building life cycle. Source: UNEP SBCI 2010.

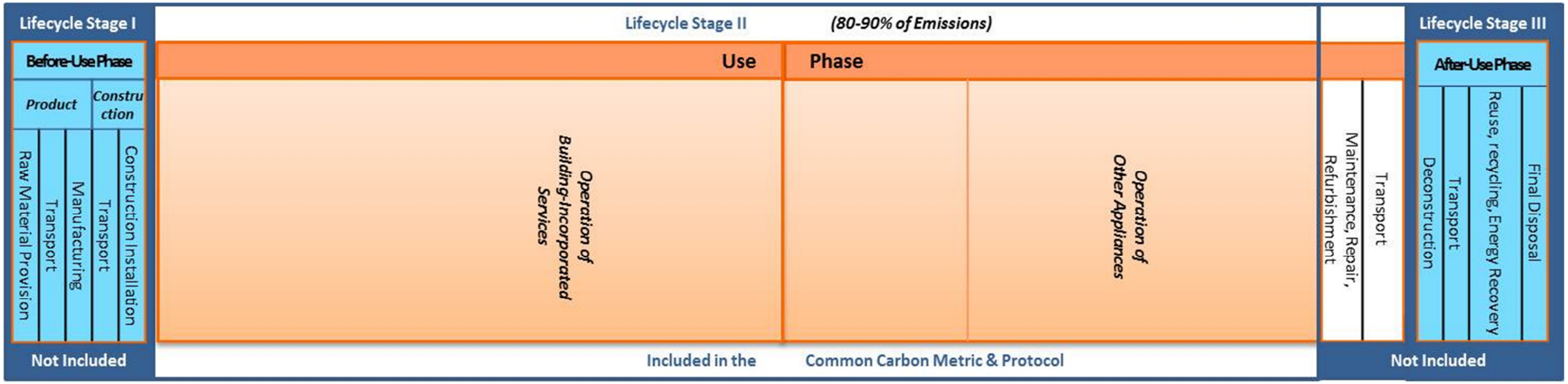
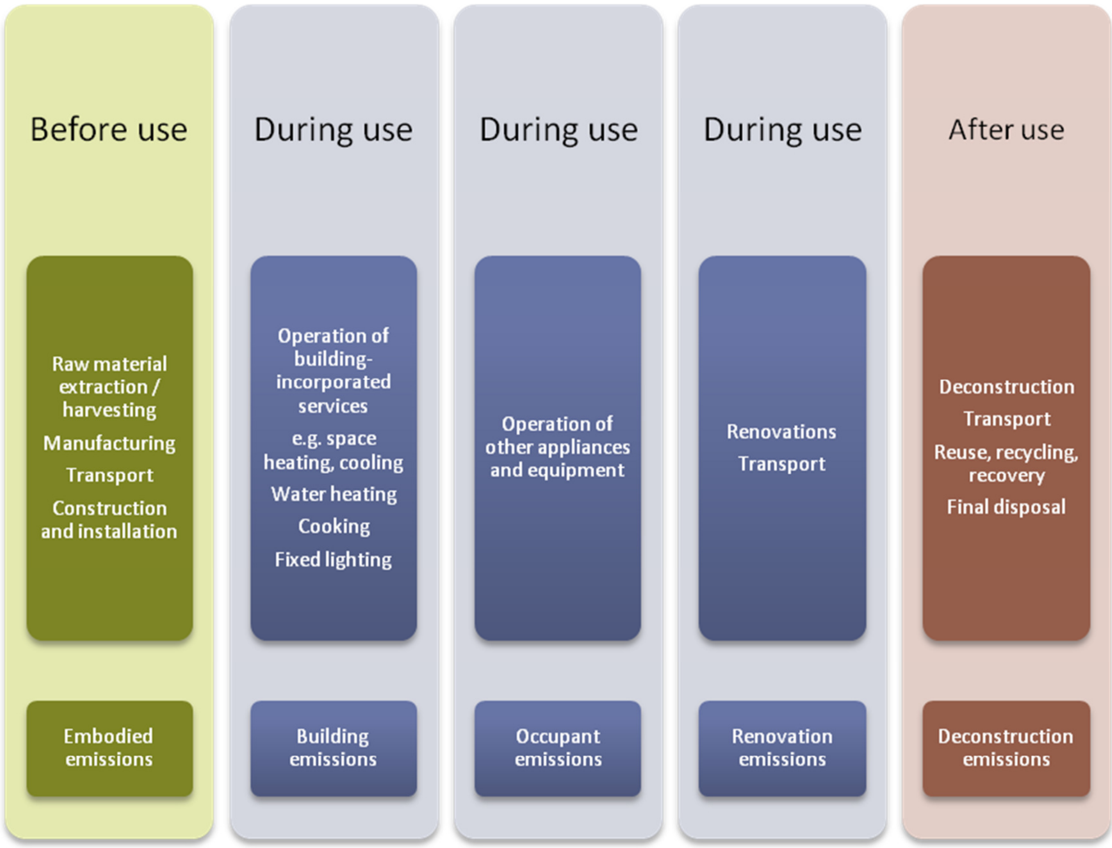


Figure 2: Conceptual breakdown of building life cycle. Adapted from the United Nations Environment Programme's Common Carbon Metric (UNEP SBCI 2010)**.**



3.1.1 Embodied Emissions

Embodied emissions are emissions that were generated in all of the processes prior to operation of the building. Embodied emissions include emissions from the extraction and processing of raw materials, manufacturing of materials and equipment for use in the building, transport of materials and equipment to the site and the construction and installation of the building structure, systems and equipment. Different definitions of a zero carbon building may include all or some of these sources of embodied emissions.

Amongst the definitions and initiatives reviewed, few included embodied emissions. One demonstration project, the Australian Zero Emission House Project, did seek to include embodied emissions in its definition of a zero carbon building. Including embodied energy and emissions enables the full life cycle of the building impact to be included and thus this boundary would enable the most comprehensive coverage of emissions and thereby theoretically result in the greatest reduction of the environmental impact of the built environment.

However, including embodied emissions poses several problems:

- Calculating embodied emissions is relatively complex and data can be difficult to obtain for the full range of materials in use

- When regulatory or other initiatives to measure and reduce greenhouse gas emissions already cover the sectors upstream of the building, there is potential for double counting of emissions
- Obtaining data on embodied emissions for existing buildings is challenging, given that the materials used in existing buildings may not be fully known and the embodied emissions associated with those materials are very difficult to calculate retrospectively.

Consequently, most definitions exclude embodied emissions and focus on operational emissions.

3.1.2 Building Emissions

Building emissions are those associated with energy consuming equipment that is 'built in' to the building or site (and 'built on', in the case of renewable energy generation technologies that may be installed on-site).In non-residential buildings, the term 'base building' is commonly used to represent what is already in place before a tenant moves in and does a fit out. Tenants often have little involvement in decisions about what equipment to install in the base building.

In residential buildings, the term 'base building' is not typically used and the boundary between builder decisions and occupant decisions is less sharp. Home owners are usually more involved in decisions about appliances and equipment that will be built into the fabric of the home. Sources of emissions that are built into the dwelling can include the thermal fabric (and associated space heating and cooling equipment), water heating, built-in cooking appliances (stovetops and ovens), fixed lighting, ventilation, pool heating, pool pumps and shared infrastructure such as lifts in apartments.

For our purposes, it is still useful to make a conceptual distinction between emissions associated with building-incorporated services that are essentially fixed at the time of building delivery and those associated with appliances and equipment brought into the building by the occupant. These emissions are what we define as 'building emissions' in Figure 2.

Inclusion of building emissions in definitions of zero carbon buildings is essentially universal. However, there is substantial variation in what sources of emissions are defined to be part of the building. Some definitions are only concerned with the building fabric and associated space heating and cooling, such as NatHERS and the Passivhaus Standard. Others extend on these building services to include hot water and ventilation (such as the European Directive on the Energy Performance of Buildings). Inclusion of fixed lighting and built-in cooking appliances is rarer.

3.1.3 Occupant Emissions

Occupant operational emissions are those associated with the use of occupant-provided equipment (i.e. equipment that is not 'built in' to the building) such as appliances including kettles, microwaves, washing machines, computers, televisions, portable heaters, fans etc. They are much more dependent on the lifestyle and decisions of the occupant than building emissions.

Most building regulation concentrates on 'building emissions' and leaves subsequent decisions about levels of consumption and choice of appliances to the occupant. Regulators do not see it as their role to regulate lifestyle. For this reason many definitions and initiatives have chosen not to include occupant emissions. However, occupant emissions can be significant. Reflecting this is the considerable discussion afforded to occupant impact within the literature reviewed.

Most definitions that include this type of impact are theoretical only or under review, such as the current definition that exists in the UK Code for Sustainable Homes. The practicality of including occupant emissions in the UK's definition of a zero carbon home has been subject to considerable debate and a recent review of the definition made the recommendation that occupant emissions are withdrawn from the scope. This decision was arrived at on the basis that it is impractical to include occupant related ('un-regulated') emissions and that not to include this type of impact is in line with most other countries policy ambitions (DCLG UK 2011). Initiatives that have attempted to include this type of impact fall largely in the realm of demonstration and experimental projects such as the Australian Zero Emission House Project.

While a definition that includes occupant emissions would be more complete and could help to drive greater emission reductions, there are justifications for excluding occupant emissions from regulation. Generally, other regulatory schemes are already in place to drive reductions in occupant emissions. In Australia there are mandatory and voluntary schemes in place to manage major appliances, e.g. energy labelling and minimum energy performance standards (MEPS) for major appliances (including household refrigerators and freezers, commercial refrigeration, televisions and commercial building chillers). Gas cookers are covered by a voluntary gas labelling program.

3.1.4 Renovation and Deconstruction Emissions

UNEP SBCI (2010) uses the term *maintenance* emissions to define a separate category of emissions. However, such a term is problematic as it is unclear what the distinction is between maintenance emissions and occupant emissions. For example, are emissions associated with using a vacuum cleaner to clean the floor, or using a drill to put up a picture classified as maintenance or occupant emissions? If they were maintenance emissions, how would we go about measuring them separately (and why)?

We have instead made a distinction between occupant emissions and renovation emissions. Regular, routine maintenance, such as cleaning the house, fixing things that break and façade cleaning (in the case of commercial buildings) is defined as part of occupant emissions. Renovation emissions are emissions associated with substantial changes to the building, usually involving the use of external energy-using equipment and building professionals. Re-carpeting, re-painting and extensions would all generate renovation emissions. Transport emissions during renovation activities are also included in this boundary.

Emissions associated with the *deconstruction* of a building may include emissions from demolishing the building, transport during this process, and those resulting from re-use, recycling and final disposal of waste material. Some or all of these impacts may be included, raising further points of potential variation.

Including either or both of these types of emissions extends the life cycle of the building that is being covered, thus leading to a more complete coverage of the building impact. However such emissions are not commonly covered given that they are difficult to calculate and, in the case of deconstruction emissions, may be far in the future.

3.1.5 Recommendation

The elements of the building life cycle that should be included in a definition depend heavily on the purpose for which the definition is to be used. For regulatory and voluntary initiatives, it is most feasible to focus on building emissions only. However, some developers may wish to push further and include occupant emissions, and some research and demonstration projects may wish to use a definition that covers the full life cycle for theoretical completeness.

We therefore recommend the use of a hierarchy of standard terms in definitions to represent the parts of the building life cycle that are covered.

Figure 2 provides one logical basis for such a hierarchy:

- Zero carbon building, which includes the 'building emissions' shown in Figure 2
- Zero carbon occupied building, which includes the 'building emissions' and 'occupant emissions' shown in Figure 2
- Zero carbon embodied, occupied building, which includes the 'embodied emissions', 'building emissions' and 'occupant emissions' shown in Figure 2
- Zero carbon life cycle, which includes all emissions shown in Figure 2.

We recommend use of the zero carbon building definition above as the starting point for new regulatory and voluntary initiatives. This is the most common definition in current use, as it is easiest to model and is considered an appropriate target for regulation. Definitions that go further could use the terminology defined above, for consistency and comparability.

This recommended terminology has a logical basis (in Figure 2) but should be understood as tentative. The terminology needs to be tested against various use scenarios; such testing is outside the scope of this study.

We recognise that these terms are not particularly user-friendly – it is difficult to adequately cover the complexity and range of options across the building life-cycle in a simple way. One way to simplify the terms would be to assign classes or types to each category, e.g. a Class 1 zero carbon building would cover building emissions, a Class 2 zero carbon building would cover building and occupant emissions etc. Further work, beyond the scope of this report, would be required to develop a suitable classification scheme.

Further work is also needed to define the precise end-uses included in each definition. For example, cooking emissions could be defined as occupant emissions instead of building emissions. There may also be differences between residential and non-residential buildings in the importance of including particular end uses. Further, the lists of end uses in Figure 2 are intended as examples and are not exhaustive. Building emissions could also include ventilation, swimming pool heating, swimming pool pumps and lifts in apartments (for example). Specific regulatory applications and voluntary initiatives should undertake further cost-benefit analysis and consultation to determine whether inclusion of some of these end uses (e.g. cooking appliances) is justified. Such analysis was beyond the scope of this project.

3.2 Assessment methods and Metrics

The methods and metrics used to assess and define building performance are a major source of variation across the definitions reviewed during this project. This section reviews different metrics used in definitions, assessment methods used in existing Australian building rating tools and how performance is assessed under different definitions.

3.2.1 Metrics

The metric used to assess building impact is one of the main sources of variation across definitions of low impact buildings. The metrics used in different definitions include:

- Delivered or site energy, i.e. the amount of energy actually used in the building
- Primary or source energy, i.e. taking into account conversion and transport losses associated with different energy forms and carriers

- Greenhouse gas emissions, usually limited to those associated with energy use
- Energy costs, where the aim is to achieve zero energy bills
- Exergy, which refers to balancing the useful work available (Sartori et al. 2010b; Marszal et al. 2011).

These metrics each have advantages and disadvantages, which are reviewed by several authors (Sartori et al. 2010b; Marszal et al. 2011; Voss, Musall & Lichtme 2011). Site energy is relatively easy to measure but does not give a true indication of the impact of a building, as it fails to take into account differences in conversion efficiency and losses for different energy sources. Primary energy is the most commonly used metric as it addresses this issue. However, where responding to climate change is a stronger objective than energy security, primary energy is less useful; in theory, if achieving a net zero energy balance is the only requirement, a building could achieve net zero primary energy by installing a diesel generator on-site, which would not be desirable from a climate change perspective. Here, greenhouse gas emissions are a preferable metric. Using energy costs as the metric is problematic due to price fluctuations and political influence on prices. Exergy is a very technical concept that is difficult to comprehend for regulators and difficult to communicate to the public, although it is useful for evaluating technical solutions.

Although primary energy remains the most commonly used metric in existing definitions of low impact buildings, greenhouse gas emissions are an increasingly common metric(UNEP SBCI 2010). One of the reasons for the popularity of primary energy use is that the regulatory focus in building codes has been on regulation of energy use and the European Directive on Energy Performance in Buildings has this focus (K. Voss, pers. comm., 25 June 2011). However, some countries are beginning to adopt greenhouse gas emissions as their preferred metric and it is likely that both will be used in the future (K. Voss, pers. comm., 25 June 2011).

Given Australia's abundant energy resources, the primary reason for pursuing zero impact buildings is not to improve energy security but to reduce greenhouse gas emissions and respond to climate change. Using greenhouse gas emissions as the metric for the definition allows for full accounting for emission reduction options of different kinds and incorporation into broader carbon footprints. As we will see below, existing Australian building rating tools also uses this metric. Rather than zero greenhouse gas emissions, our preferred terminology is zero carbon, for simplicity and brevity.

3.2.2 Assessment methods in Australian Building Rating Tools

The main Australian building rating tools are NatHERS, NABERS and Green Star. Below, we examine how each tool rates building performance and whether there are definitions of zero impact stated or implied in each definition.

NatHERS

The Nationwide House Energy Rating Scheme (NatHERS) is a rating tool to assess the thermal performance of homes. It only assesses the thermal efficiency, which is part of the building emissions discussed in Section 3.1. 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.

Because NatHERS only covers part of the base building load it cannot be used on its own to determine whether a building meets a zero carbon definition, but it could contribute towards such an assessment. The energy demand would need to be converted to greenhouse gas emissions using data or assumptions about fuel use and appropriate emission factors. Other tools would be needed to assess other building loads (such as water heating and cooking) and the impact of emission reduction options.

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.

NABERS

The National Australian Built Environment Rating System (NABERS) assesses the performance of existing buildings based on monitoring of their actual energy use. The NABERS Energy tool for offices offers ratings for the base building, tenancy, and whole building, so it takes into account the full range of operational impact discussed in Section 3.1. NABERS also allows for inclusion of Green Power as a way of reducing greenhouse gas emissions.[3]

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.

Under the Australian Government's Commercial Building Disclosure program, sellers or lessors of commercial buildings with floor area greater than 2,000 m^2 must obtain and disclose an up to date energy rating. Currently, a valid NABERS rating for the whole or base building is sufficient. From November 2011, a Building Energy Efficiency Certificate is required, which includes a NABERS Energy rating for the building. Consequently, familiarity with NABERS ratings is likely to greatly increase in the years ahead, at least in the commercial buildings sector.

NABERS has been in operation for over ten years and some 5% of ratings are now achieving 5 stars or higher. To reward high achievers, NABERS recently proposed extending the rating scale beyond 5 stars and creating a logical end point for the scale at zero emissions. Consultation on the extension of the rating scale is still ongoing. If the revised scale is adopted, NABERS offers a possible tool for assessing whether buildings achieve zero carbon during operation.

This proposal could potentially apply to all building types currently covered by NABERS, including office buildings, hotels, shopping centres and future tools for data centres, schools and hospitals.

[3] However, Green Power is excluded from NABERS ratings used to comply with the Australian Government's Commercial Building Disclosure scheme, described below.

GreenStar

GreenStar is a suite of voluntary building rating tools provided by the Green Building Council Australia. 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 GreenStar multi-residential tool establishes a standard practice energy benchmark and awards point for percentage reductions from this benchmark. A 100% reduction is awarded the maximum twenty points for greenhouse gas emissions. This is defined as ‘zero net operating emissions’.

The point allocation is based on results from GreenStar’s energy calculator, which takes into account thermal performance, heating, ventilation and air conditioning, lighting, hot water, mechanical ventilation, lifts and other amenities, cooking and on-site electricity generation. In other words, the rating covers the full range of base building energy demand identified in Section 3.1. This means that the assessment approach is quite consistent with assessing a zero carbon base building definition. However, GreenStar relies on definition of a benchmark building from which to calculate emission reductions. A better approach for new regulatory and voluntary initiatives would be to have actual rather than relative assessment of emissions.

3.2.3 Modelled or monitored performance

Compliance with a zero carbon definition can be assessed either by modelling the theoretical performance of a building or by monitoring its actual performance. Regulatory and voluntary initiatives exist that use both modelling and monitoring, although the two approaches are usually used separately and associated with different regulations, rating systems or awards.

The choice between use of modelling or monitoring to assess compliance with a zero carbon definition depends very much on the specific application. Where the focus is on regulating to ensure that a building meets certain requirements during design and at completion, it makes more sense to base compliance on modelled performance. To use actual performance data, regulators would need to collect data on energy use for a year and then require some form of rectification if the performance fell short of requirements. This is probably not a feasible approach.

However, where the focus is on shifting existing buildings towards zero carbon, modelled data may be of more value. For example, the Australian Government’s Commercial Building Disclosure program requires assessments of energy efficiency based on actual performance.

One of the challenges faced when using actual performance data to assess compliance with a zero carbon definition is that many definitions focus on a limited range of building-incorporated end uses. Sub-metering is often inadequate to separate out these end uses from total energy use, particularly for residential buildings.

Consequently, few regulatory zero carbon definitions to date rely on monitoring of actual performance, even though this would provide the most accurate assessment of whether a building complies with a zero carbon definition. The Australian Government’s Commercial Building Disclosure program is an exception, although it is focused on commercial buildings and does not include a zero carbon definition.

The important point to make here is that there is no reason why a single definition cannot be used to support both modelling of performance and measurement of actual performance.

3.2.4 Assessment Method

While there is significant variation in assessment methods used to determine compliance with particular zero impact definitions, much of the variation is due to the different scope and metrics discussed above. Taking these differences into account, the assessment methods are reasonably consistent (Marszal et al. 2011). The task is to estimate building energy demand for the end uses that are within the scope, to use emission factors to convert energy demand into greenhouse gas emissions, and to assess the impact of emission reduction options such as PV panels on net energy demand and emissions.

In an attempt to increase standardisation of assessment methods, the United Nations Environment Programme (UNEP) has led the development of a Common Carbon Metric & Protocol for assessing building performance, using kg CO_2-e/m^2/year as the key metric (UNEP SBCI 2010). Alignment with this Common Carbon Metric & Protocol is recommended to allow comparability of building performance data internationally, although climatic differences do raise questions about the value of such comparability.

The Common Carbon Metric & Protocol focuses on Scope 1 and 2 emissions, excluding Scope 3 emissions(UNEP SBCI 2010). Australia's National Greenhouse and Energy Reporting System (NGERS) adopts a similar approach. We recommend that a zero carbon definition also focuses on Scope 1 and 2 emissions, for two main reasons. First, this will align the definition with Australia's main system of reporting of energy and greenhouse data (NGERS), as well as with the international Common Carbon Metric & Protocol. This will provide greater consistency in data and support international comparisons.

Second, inclusion of Scope 3 emissions increases the risk of double counting of emissions, particularly as the scope of regulation of greenhouse gas emissions increases. Scope 3 emissions are indirect emissions and are likely to be subject to regulation in the sector in which they are generated.

The development of detailed assessment methods for assessing compliance with a zero carbon definition becomes more important if the definition is used for specific regulatory or voluntary initiatives. However, some of the features of a suitable assessment method are already clear and are outlined below.

3.2.5 Recommendation

We recommend the following in relation to assessment method and metrics:

- An appropriate metric would be carbon intensity in kg CO_2-e/m^2/yr for consistency with the UNEP work. This requires collection of data on gross floor area. The metric should be absolute, rather than a reduction from a benchmark.
- Only Scope 1 and 2 emissions should be included.
- The assessment method should be able to model performance at least for base building end uses, including space conditioning, water heating, cooking and shared lighting. NatHERS can be used to model energy demand for space conditioning but new modelling approaches or deemed energy demands and greenhouse gas emissions would be needed for the other end uses. NatHERS could be expanded to cover these additional end uses or new tools or regulatory guidelines could be developed.

3.3 Timeframe

The timeframes for assessing achievement of zero impact in different definitions include monthly, seasonal, annual and full-life cycle. Annual is by far the most common of the definitions that we reviewed. Typically the focus is on zero annual impact because most definitions have an operational focus and don't take into account embodied energy/emissions or deconstruction. However, an assessment of each timeframe was conducted to determine what timeframe would best suit the Australian context (political, economic and climatic). The choice of timeframe has significant implications for methodology selection, technical requirements, feasibility of implementation and the extent to which the true environmental impact can be measured.

3.3.1 Full-life cycle

This timeframe enables calculation of operational impacts, embodied impact of the building materials and any installed renewable energy generation technologies, as well as construction, and deconstruction impacts. When these are taken into account, a 50-year building lifetime is commonly assumed (for example, this is the approach that Grocon has taken for assessing carbon neutrality for its Pixel building in Melbourne). However, few definitions cover the entire building life cycle. Whilst a full life cycle timeframe enables a truer account of the impact of the building it is significantly more resource intensive to assess. This can reduce uptake and reduce the impact of the initiative.

3.3.2 Annual

Calculating the energy/carbon balance on an annual basis is the most common approach (e.g, UK Code for Sustainable Homes, Canada's current approach recommended by the Net Zero Energy Home Coalition, and the EnergGuide Rating System). An annual balance enables the full operational impact of the building to be accounted for.

In some approaches, the intent is to develop a building that is energy or carbon positive on an annual basis, i.e. the building generates more energy than it uses, or offsets more emissions than it creates. An annual carbon positive building can pay off its embodied carbon debt over time.

3.3.3 Monthly/seasonal

A monthly or seasonal timeframe is used in some definitions but is very rare. It is difficult to achieve a zero emissions balance on a seasonal timeframe and even more so on a monthly basis due to seasonal and monthly fluctuations in availability of on-site renewable energy (e.g. less output from solar panels in winter). The reason that some definitions adopt these shorter timeframes is to reduce demand on electricity infrastructure by ensuring that there is little or no import from the grid.

3.3.4 Recommendation

Zero carbon definitions in Australia should require achievement of net zero emissions on an annual basis, consistent with most other definitions. This is the most feasible, cost-effective approach, allowing consideration of all operational emissions.

Some developers may wish to go beyond the requirement for an annual zero carbon balance to achieve an annual positive balance, as a way of paying off embodied carbon debt over time.

3.4 Grid connection

While there are a number of self-sufficient, off-grid or autonomous zero carbon demonstration buildings, most mainstream definitions of zero impact allow for grid connection. As such, most definitions focus on zero net impact, rather than zero on-site impact. The main rationale behind allowing some importation of energy is that it is more cost-effective than forcing all energy to be generated on-site and excess to be stored in batteries (DCLG UK 2011). Additionally, the grid is a resource to be used, and since we have it, it does not make sense to abandon this resource and replace it with batteries, particularly in areas of high population density (Vale and Vale, 2002 in Marszal et al., 2011).

Nevertheless, there are issues of load matching, peak energy demand and grid stability associated with grid connected zero carbon buildings. Specifically, there may be technical grid management issues associated with large penetrations of household scale renewable generation. Additionally, spikes in demand or peak demand for electricity are currently driving investment in new electricity network and generation infrastructure. If zero carbon buildings have high peak demand that is not closely matched temporally by on-site generation, this can increase the need for fossil fuel generators. Further, allowing for grid connection does indirectly support the use of fossil fuel generated electricity, as fossil fuel generators are currently used to stabilise and supply much of the electricity grid.

For the reasons above, autonomous or off-grid zero carbon buildings are likely to deliver lower overall impact than grid-connected zero carbon buildings. Some developers may wish to go beyond the achievement of zero net carbon buildings to achieve zero carbon autonomous buildings.

If there is a large rollout of grid-connected zero carbon buildings in the future, further analysis of the implications for electricity network infrastructure would be recommended. Additionally, there would be a need to maximise load matching through demand response strategies. These issues could ultimately be addressed by adding conditional requirements (e.g. maximum peak load) to a zero carbon definition (see Section 3.9 for further discussion of conditional requirements).

3.4.1 Recommendation

ISF recommends that grid connection be allowed (but not required) within the definition of a zero carbon building, which will mean that Australia has a net zero carbon building definition. Buildings that are not grid-connected should use distinguishing language to indicate the stronger definition that applies; we recommend calling these building zero carbon autonomous buildings.

3.5 Sectoral differences

Whilst the focus of this project is on the residential sector consideration has also been given to non-residential and mixed (residential and commercial) buildings, both to gain insight into factors considered in other definitions and to allow for the development of consistent definitions that can be used across sectors.

Zero Carbon Hub (2011) encourages a consistent approach between domestic and non-domestic buildings, pointing out that 'consistency of approach aids understanding, particularly given the large number of mixed-use developments and the fact that future energy planning is likely to be community rather than building based'. There is no theoretical reason why a single zero carbon building definition cannot be consistently applied across sectors. The discussion so far on life cycle boundaries, assessment methods, timeframe and grid connection applies equally to residential, commercial, industrial and mixed-used buildings. There will be some variation in what is included in the base building definition for different building types but this should not change the basic definition.

The important differences between sectors are not at the definitional level but relate to implementation. The different physical characteristics of residential, commercial, industrial and mixed-use buildings make different emission reduction opportunities feasible. For example, industrial buildings might have a larger proportion of available roof space for solar panels than residential buildings.

The different opportunities for emission reduction extend beyond physical differences to include the nature of the sector i.e. different energy demands. As noted by the UK Zero Carbon Hub (2011, p20), 'many high rise apartment blocks are part of mixed use developments…including retail and other uses which create specific demands (and opportunities) for infrastructure and services'. These differences make it particularly challenging to set one size fits all requirements for energy efficiency and on-site renewable energy generation.

In response, Zero Carbon Hub recommended that a specialist group with expertise in the development of non-domestic buildings conduct further work on the appropriate carbon compliance limits for non-domestic buildings. Currently different limits have been proposed for hotels, offices (three different types), retail, schools, supermarkets and warehouses (two types) (Zero Carbon Hub 2011, p25). Similarly, the MINERGIE Standard has identified 12 different building sectors and has set different limiting values for each and enables different input data for each. Australian building rating tools, like Green Star, have taken a similar approach of establishing different carbon intensity expectations for different building sectors and building types.

One response to the different opportunities in different sectors is to adopt an aggregated approach, in which zero carbon is the overall objective but different sectors make different contributions towards that objective. An aggregated approach currently exists for non-domestic buildings in the UK(Part L 2010 of UK Sustainable Building Code). However, whilst an aggregated approach allows for flexibility in response to the variation in energy efficiency and renewable energy opportunities that exist between different building sectors it does not guarantee an overall zero balance as this will depend on actual build mix. The Zero Carbon Hub has recognized this issue but no appropriate response has yet been determined (Zero Carbon Hub, 2011, p7) .

3.5.1 Recommendation

The definitions proposed in this report are intended to apply across sectors, while noting that there will be differences in implementation across sectors. These differences primarily relate to the specific building-incorporated services included in the building definition, modelling and assessment methods used in different sectors (e.g. different rating tools) and the feasibility of particular emission reduction options.

3.6 Building type

Similar to the sectoral differences discussed above, there is no reason why a single zero carbon definition cannot cover multiple building types. Again, the differences are in implementation rather than definition. Due to their physical characteristics, different building types will have different opportunities and challenges with respect to energy efficiency and on-site renewable energy generation opportunities. Therefore, it may not be appropriate to place the same requirements on different building types when implementing a zero carbon definition.

This section looks at two distinctions between building types:

1. New buildings vs existing building
2. Different dwelling types, i.e. detached houses, semi-detached houses and apartments.

3.6.1 New building and existing buildings

Almost all regulatory and voluntary targets relating to zero energy/carbon buildings are exclusively focused on new rather than existing buildings. The target of the European Directive on the Energy Performance of Buildings is to have all *new* buildings be nearly zero-energy buildings by 31 December 2020, the 2030 Challenge has the target for all *new* buildings to be carbon neutral by 2030, and the UK's policy commitment is to ensure that all *new* homes are zero carbon by 2016. Common reasons include the expense of retrofitting to increase the energy efficiency of the building shell, the increased difficulty of installing some zero and low carbon technologies such as heat pumps, and the increased complexity of calculating embodied energy for existing buildings.

Marzsal et al (2011) note that in principle it is possible for an existing building to balance its energy consumption with on-site renewable energy generation, however they acknowledge that in most cases to achieve this would require a very large solar photovoltaic system. This highlights the potentially significant cost and technical feasibility issues that come into play when requiring existing buildings to comply with a zero carbon definition. New buildings can design in energy efficiency and appropriate orientation to minimise the need for renewable energy, whereas existing buildings are constrained in what they can achieve at a reasonable cost.

As noted above, this does not mean the definition needs to change. Instead, consideration needs to be given to whether existing buildings should be required to achieve such a definition and under what circumstances. For example, the MINERGIE Standard recognises the different challenges for existing buildings and has created a MINERGIE renovation standard, which sets significantly less stringent limiting values for existing buildings than zero carbon (e.g. 60kWh/m^2 for residential buildings). While standards for existing buildings may fall short of a zero carbon definition, they should ideally use a consistent assessment method and metrics to allow comparison.

3.6.2 Detached houses, Semi-Detached houses and apartments

The physical differences that exist between detached houses, semi-detached houses and apartments create potentially significant differences in opportunities for energy efficiency and on-site renewable energy generation. This is largely as a result of differing roof space for the installation of PV systems and different wall to floor ratios affecting insulation potentials.

The Zero Carbon Hub (2011) recently explored and analysed the technical and commercial feasibility of meeting certain energy efficiency and on-site renewable energy generation standards for a range of different house types and sizes. This included modelling of the amount of PV required to achieve different levels of Carbon Compliance. Carbon Compliance refers to a combination of two requirements – a requirement for energy efficiency and a requirement for on-site renewable energy generation (please refer to Section 3.8 for more detail on these limits). The results of this analysis led to the recommendations that different Carbon Compliance limits be set for dwelling types that have significantly different energy efficiency and renewable energy generation opportunities. Zero Carbon

Hub identified these as detached houses, attached houses, low-rise (four storeys and below) and high-rise apartments.

As noted in Section 3.5, similar distinctions can be drawn between different types of non-residential buildings.

3.6.3 Recommendation

Appreciating that the ultimate purpose of implementing a zero carbon definition is to reduce the environmental impact of the total building sector it is important and valuable to ensure that existing buildings and the full range of dwelling types are covered in any definition of zero emission buildings. The definitions proposed in this report are intended to cover all residential building types (new, existing, detached, semi-detached and low and high-rise apartments) and non-residential building types (e.g. offices, industrial, hospitals, schools and universities, shopping centres), while recognising that it will not be practical to require all of these building types to achieve a zero carbon definition in the short-term. Different standards should be required of new and existing buildings, and of different building types, reflecting the different opportunities and challenges faced by each in being energy efficient and generating renewable energy on-site.

3.7 Spatial Boundary

An important source of variation between definitions of zero impact is where they draw the spatial boundary, or the scale that they apply to. While the focus of this project is on building-scale definitions, we reviewed other scales as follows:

- Detached homes, e.g. Australian Zero Emission House Project
- Residential Buildings, e.g. Green Star, HERS Index, UK Code for Sustainable Homes, Canada R-2000 Standard
- All buildings, e.g. European Directive on the Energy Performance of Buildings, the 2030 Challenge, MINERGIE Standard, Passivhaus Standard, UNDP Common Carbon Metric
- Precinct or community scale, e.g. Climate Positive, One Planet Living, Zero Emission Neighbourhoods
- City scale, e.g. Carbon Neutral Seattle.

A positive aspect of zero carbon and energy innovation is that it is possible at multiple scales. However, appropriate zero carbon definitions for different scales vary. An advantage of building-scale definitions is that they have clear boundaries that can be easily communicated, measured and understood, and they exist as a common single entity. However, there are challenges related to the allocation of emission reductions from shared infrastructure to individual buildings (see Section 3.8 for further consideration of this issue). Further, differences between buildings make it difficult for all buildings to achieve a universal definition. Precinct or community scale definitions address both of these challenges by setting a wider spatial boundary. This allows emission reduction options within the precinct or community, such as a community solar installation, to be included without worrying about how to allocate them to specific buildings. It also allows different buildings to achieve different standards, as long as the overall precinct or community requirement is achieved.

As a result, scaling up a building-scale definition to a precinct scale is not necessarily straightforward. New emission sources become more important at a precinct scale, such as transport within the precinct, emissions from industrial facilities and emissions associated with public infrastructure. A precinct is not zero carbon just because all the buildings within the precinct are zero carbon. This issue becomes even more pronounced at a city scale, when emissions associated with city transport, waste disposal, wastewater treatment, industry and the like move within the boundary.

Nevertheless, it is possible to expand the building-scale definitions presented here to a precinct scale. The easiest way is to exclude emission sources that are not directly related to buildings. The building-scale definition can then be applied across multiple buildings. Shared infrastructure, such as shared renewable energy installations, could be incorporated into such a definition without necessarily expanding to include other emission sources within the precinct.

While precinct or community scale definitions have a lot of merit for moving towards zero carbon, they tend to be applied to new precincts or communities, where a single developer or organisation has authority. Further, as discussed above, achieving zero carbon is much easier in new developments. For existing precincts and communities, there are no clear mechanisms to get commitment from stakeholders to a zero carbon objective. In addition, it is more challenging to reach zero carbon in new buildings. As such, definitions at this scale are unlikely to gain much momentum for existing precincts and communities in the near future.

3.7.1 Recommendation

Precinct, community and city-scale initiatives to achieve zero carbon are valuable and can exist alongside building-scale approaches. However, the focus of this project is on developing a building-scale definition. Scaling up the building-scale definition proposed here to other scales is possible but requires attention to new emission sources that are introduced as the spatial scale increases.

3.8 Allowable Emission Reduction options

3.8.1 Option Categories

A feature of many of the zero carbon definitions we have reviewed is that they place limits on the emission reduction options that can be used to achieve zero emissions. Torcellini et al (2006) divide emission reduction options for buildings into the following categories:

- Reduce site energy use through low-energy building technologies (e.g. daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, passive design)
- On-site supply options
  - Use renewable energy sources available within the building's footprint
  - Use renewable energy sources available at the site
- Off-site supply options
  - Use renewable energy sources available off-site to generate energy on-site (e.g. import of wood pellets or biodiesel for use on-site)
  - Purchase off-site renewable energy sources.

For Torcellini et al (2006) this hierarchy expresses an order of preference, from top to bottom.

3.8.2 Energy efficiency

All definitions we examined stress the importance of energy efficient design and construction and prioritise energy efficiency over renewable energy options. According to Marszal et al, 'it is almost always easier to save energy than to produce energy', so prioritising energy savings is a logical approach to zero impact buildings. While energy efficiency is important, it is impossible to achieve zero impact through energy efficiency alone; the remainder of a building's energy needs must be met from zero or low carbon energy sources, either on- or off-site.

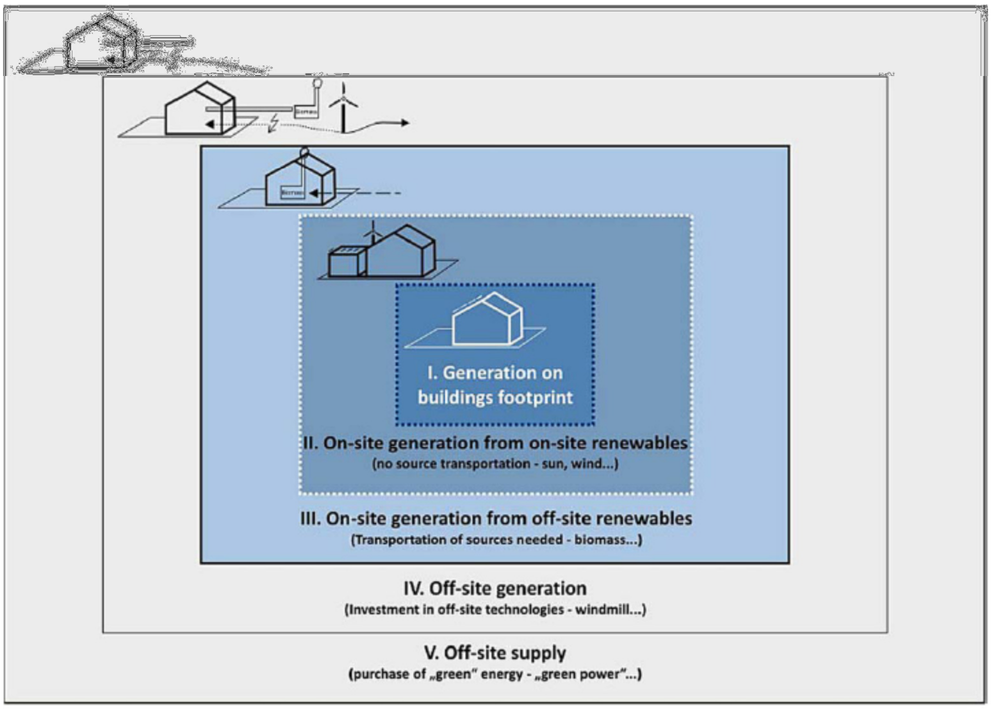
Sartori et al (2010) argue that reasonably stringent energy efficiency requirements should accompany efforts to achieve net zero impact. The definition of a 'zero energy building' provided by Torcellini et al (2010) reflects an appreciation of this, 'a residential or commercial building with greatly reduced energy needs through efficiency gains'.

The absence of energy efficiency requirements may lead to the installation of oversized renewable energy generation systems which would not have the intended effect of achieving the most cost-effective reduction in the environmental impact of the built environment. If Australia was to include an energy efficiency requirement as part of its zero carbon definition, which we recommend, different standards should be set for different building types, as is the approach in the UK (see Section 3.6). Standards could be expressed as a NatHERS rating with additional requirements set for end uses not covered by NatHERS, or a new assessment method could be developed.

In setting these standards thought should be given to their economic implications and technical feasibility; there is a balance to be struck between improvements to the building fabric and reliance on clean energy sources. In work by CSIRO, pursuing energy efficiency as a way of getting to zero impact seems to be cost-effective for new buildings up to a NatHERS rating of about 8.5 stars; at that point, it is more cost-effective to turn to renewable energy than to seek further improvements in the thermal shell (G. Foliente, pers. comm., 9 June 2011). For existing buildings, the point at which it becomes more cost-effective to turn to renewable energy will be different, as it typically costs more to retrofit for energy efficiency than to design it in from the start.

While Marszal et al (2010) agree that energy efficiency should be prioritised over low-carbon energy, they do not agree with Torcellini et al (2006) that there is necessarily a hierarchy of preferred low-carbon energy sources. Figure 3 reproduces a depiction of the spectrum of possible low-carbon energy options from Marszal et al (2010), ordered according to building proximity, not preference. We agree with this approach, as the most cost-effective options to reduce emissions may be off-site rather than on-site.

Figure 3: Overview of possible renewable energy supply options. Source: Marszal et al (2010).



3.8.3 Autonomous buildings

As discussed in Section 3.4, some zero carbon buildings aim to be autonomous, meeting all energy needs on-site without any grid connection. Zero carbon autonomous buildings only allow energy sources in categories I, II and possibly III from **Figure 3**. While there are many prototype and demonstration autonomous buildings, this level of stringency is too difficult to implement on a wide scale.

3.8.4 Net Zero Carbon buildings with on-site generation

As noted in Section 3.4, net zero carbon buildings allow connection to the electricity grid. However, some initiatives still limit allowable emission reduction options to on-site options (categories I, II and III in **Figure 3**). In this case, the grid is only used for balancing, so that on-site energy supply and demand do not have to match temporally. Electricity is drawn from the grid when needed and fed back into the grid when there is excess, achieving at least a net zero import over a specified time period. As shown in **Figure 3** and **Table 2** there are multiple options for allowable on-site energy generation and different initiatives may only allow some of these options. One issue that arises with the option of importing renewable fuel from off-site to use onsite is how to account for the carbon associated with the transport process. Ideally, it should be included when assessing performance against a zero carbon definition.

Table 2: On-site energy generation options (modified from Marszal et al (2011, p975)

On-site Energy supply options	Example Technologies	Associated level in Figure 3
1. Energy generation as part of the building footprint	PV, SHW, heat pumps and on-building wind	Level I
2. On the land title of the building	PV, SHW, low-impact hydro and on-site (but not building) wind	Level II
3. Energy generation as part of the wider building development, if a building is supplied by a private wire	PV, SHW, low-impact hydro and wind	Not included in Figure 1
4. Renewable energy resources produced off site but imported to generate energy onsite	Biomass, wood pellets, ethanol, processed waste and potentially gas (or biomass) fired combined heat and power system	Level III

3.8.5 Net zero carbon buildings with off-site emission reduction

The definitions of zero impact used by many other initiatives allow the use of off-site emission reduction options. For example, the Australian Zero Emissions House Project, allows offsets to be used to cover embodied carbon.There are three main options for offseting any energy needs and emissions beyond what energy efficiency and on-site generation can deliver. These off-site options are:

1. Investing in renewable energy or low carbon projects through a fund (Category IV in Figure 3)
2. Direct purchasing green energy, such as a Green Power Scheme (Category V in Figure 3)
3. Market based carbon purchase , through a carbon trading or accredited carbon offset scheme (not included in Figure 3).

Some definitions further require that off-site solutions or offsets be from electricity or heat generating projects; examples include the 2030 Challenge and One Planet Living. However, the UK is considering allowing non-electricity offsets, such as tree planting or transport projects, through an accredited scheme (C. Turner, pers. comms., 20 June, 2011). Australia has a National Carbon Offset Standard and could consider allowing purchase of carbon offsets that are accredited under this standard as a way of achieving zero carbon definitions.

The main challenge for all of these off-site emission reduction options is providing some assurance that emission reductions will continue to be delivered over time so that a building will remain zero carbon permanently, not just purchase zero carbon status temporarily. For example, a building owner could buy Green Power to achieve a zero carbon definition but then stop once their building had received certification. One response, commonly used in voluntary programs, is to require regular evidence (e.g. annual) that the building still meets the definition.

Another response is to develop a ‘Community Energy Fund’ that building developers pay into, which is then used to deliver community-scale (or larger scale) clean energy facilities. This approach has gained a lot of momentum in the UK, in the form of a Community Infrastructure Levy (UK Green

Building Council 2008; DCLG UK 2011). It has the potential to provide more cost-effective renewable energy than facilities on individual homes, as facilities can be developed at an appropriate scale and in the most desirable locations.

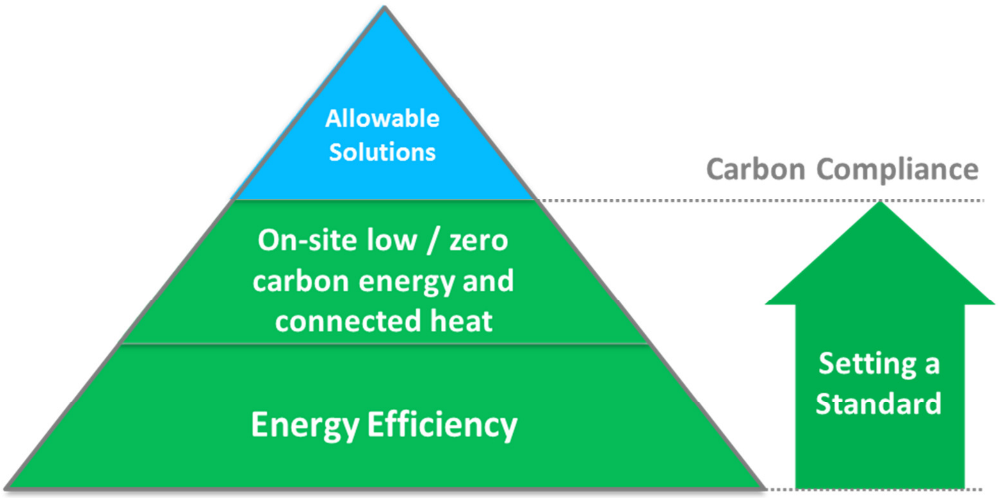
Another challenge for off-site solutions is the need to ensure that the renewables delivered to meet the zero carbon definition are truly additional to that required under other schemes, which in the UK includes the Renewables Obligation(UK Green Building Council 2008). In the case of Australia, emission reduction options would need to go beyond the requirements of the NationalRenewable Energy Target.

3.8.6 Balancing emission reduction options

Issues of economic, technical and environmental efficiency are important to consider when specifying allowable emission reduction options. While energy efficiency may be preferable, setting energy efficiency requirements too high may raise costs if it means more cost-effective clean energy options are displaced. Similarly, off-site renewable energy options at larger scales are typically cheaper than on-site renewable energy options at building scales. Requiring too much on-site renewables may again displace more cost-effective options; requiring too little may lead to minimal uptake of building-scale solutions, which would miss opportunities for reducing household energy bills and capturing economies of scale.

These competing tensions highlight the need to establish a happy medium between, or more contextual approach to, on-site and off-site energy supply options. The UK's current proposed definition has emerged from many years of considering the issue of balance between the different emission reduction option categories. The UK definition is based on a three tiered pyramid, shown in **Figure 4**, whereby a maximum carbon allowance (called 'carbon compliance' and measured in $kgCO_2/m^2/yr$) is set for energy efficiency (called the Fabric Energy Efficiency Standard) and on-site energy combined. These allowances are proposed as '14kgCO2/m²/yr for flats, 11kgCO2/m²/yr for attached houses and 10kgCO2/m²/yr for detached houses' (DCLG UK, 2011, p4). To get to zero carbon, allowable or off-site solutions can then be used to cover these final 14, 11 and 10kgCO2/m²/yr. Policy has yet to be put into place defining what allowable solutions will encompass or how they will be administered. However, it should be noted that a strong emphasis has been placed on a local approach and the opportunity to empower localities and promote local ownership (DCLG UK 2011).

Figure 4: UK definition of zero carbon buildings – emission reduction options (Zero Carbon Hub 2011).



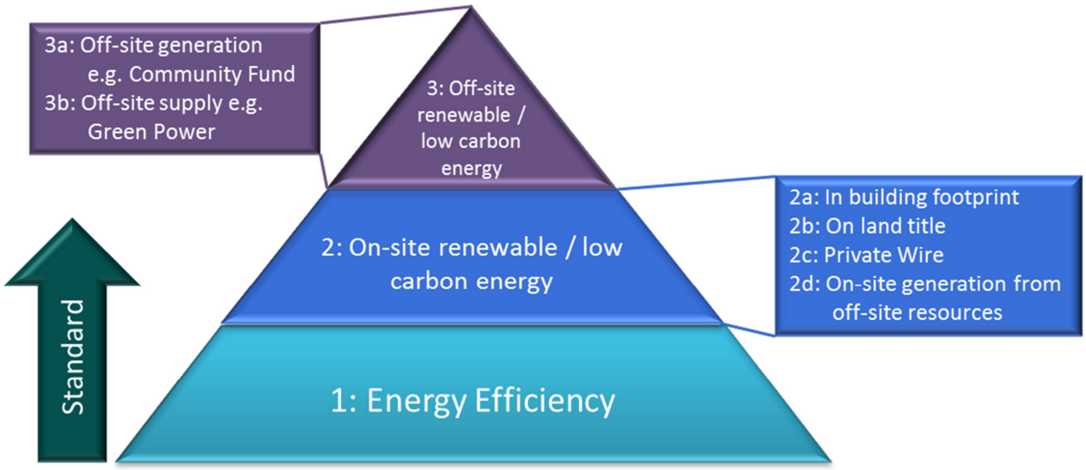
3.8.7 Recommendation

Although this starts to move beyond a zero carbon definition and into implementation details, ISF recommends a three-tiered approach to allowable emission reduction options within a standard zero carbon building definition for Australia, as shown in **Figure 5**. This should include (1) a target for energy efficiency of the building design and construction as a priority. Currently, NatHERS could be used to specify an energy efficiency standard for the building fabric. However, we recognise that NatHERS does not cover all base building end uses and may be subject to change in the future. A better approach may be to specify a limiting amount of emissions from the base building expressed as CO_2-e/m^2/yr or CO_2-e/y/occupant. Further research would be needed to set this standard.

In addition, there should be (2) a target for on-site low or zero carbon energy generation, which should be defined as encompassing all four options listed below:

a) Energy generation as part of the building footprint (2a –Figure 5)
b) Energy generation on the land title of the building (2b- Figure 5)
c) Energy generation as part of the wider building development, if a building is supplied by a private wire (2c –Figure 5)
d) Renewable energy resources produced off site but imported to generate energy onsite e.g. biomass such as wood pellets (2d – Figure 5).

Figure 5: Recommendation for Australian standard zero carbon building definition – allowable emission reduction options.



Emission reduction options 1 and 2 should be combined into a building standard of allowable emissions that can then be reduced to zero using (3) off-site solutions. It is beyond the scope of this project to propose what the targets for 1 and 2 should be; specific voluntary or regulatory initiatives would need to undertake research to determine the most appropriate standards for different building types.

Of the possible mechanisms for delivering off-site solutions, very little precedent currently exists. The idea of a Community Infrastructure Levy to support development of community-scale energy facilities, perhaps administered by local government, is worthy of further consideration in the Australian context. This kind of approach could provide a guarantee that off-site solutions are additional to existing schemes and are reliable over time, while also realising ancillary benefits associated with local empowerment, ownership and control.

3.9 Conditional requirements

As well as defining allowable emission reduction options, some initiatives set other conditional requirements as part of zero impact definitions. Conditional requirements can include:

1. Standards for base building energy efficiency (e.g. UK Code for Sustainable Homes, MINERGIE, Canada's R-2000 Standard, European Energy Performance of Buildings Directive). See Section 3.8 for discussion of this type of conditional requirement.
2. The types of emission reduction options allowed, including limits on the amount of renewable energy that can be purchased off-site (e.g. UK Code for Sustainable Homes, European Energy Performance of Buildings Directive, One Planet Living, The 2030 Challenge). See Section 3.8 for discussion of this type of conditional requirement.
3. Standards for comfort (e.g. NatHERS, MINERGIE, Canada's R-2000 Standard).
4. Standards for energy efficiency of appliances and equipment (e.g. MINERGIE, Canada's EnergyGuide labelling and its R-2000 Standard).
5. Limits on the costs incurred for meeting the zero energy or emission balance (e.g. MINERGIE).

6. Sub-metering requirements to support measurement of different end uses (no examples of this have been identified but it is something that could be considered).
7. Peak demand limits, both to limit the impact on the existing grid infrastructure, and to allow for certainty in designing new distribution systems.

The discussion below is limited to those conditional requirements that have not been considered elsewhere in the report.

3.9.1 Comfort levels

The level of comfort provided by a building is a significant factor affecting the energy performance of a building(Sartori et al. 2010a; Marszal et al. 2011). Setting comfort levels requires taking into consideration different comfort needs that come with different building types and climates (temperature and humidity levels).

The requirements of the MINERGIE standard demonstrate an appreciation of this – with comfort at the heart of this standard. Specific energy consumption is used as the main indicator to quantify the required building quality. The standard requires that buildings have "very low energy consumption". As identified in Section 3.6, MINERGIE deals with the issues raised by different dwelling types and sectors by setting different limiting values and enabling all sectors to have their own input data for indoor air temperature, air change rate and specific electricity demand. Canada's R-2000 Standard also sets requirements on indoor air quality.

In Australia, NatHERS arguably provides an indication of comfort levels, so establishment of a NatHERS rating requirement for zero carbon buildings (or equivalent) can help to ensure a desired level of building comfort. It is important to ensure that a move to zero carbon buildings does not compromise comfort levels. For example, condensation and lack of air turnover has been raised as a problem for highly sealed buildings. Specific comfort standards may need to be established as conditional requirements to address these issues. However, defining such standards is outside the scope of this study.

3.9.2 Energy efficiency of appliances and equipment

Setting energy efficiency requirements for user-related energy is a complex issue due to the lack of ability to monitor and manage it. Many of the initiatives that require energy efficient appliances do this through requiring that appliances and equipment meet particular energy rating standards under labelling systems such as the EnerGuide label in Canada and the US Energy Star label. Sartori et al (2010) recommends requiring net zero impact homes to have, whenever possible, the highest ratings available under the appropriate jurisdictions energy rating labels for appliances. In Australia this would mean requiring a particular energy rating for major appliances.

However, placing requirements on the energy performance of appliances raises significant issues. It may encourage disposal of existing appliances that still have significant life left in them. This waste issue would not be taken into account unless the net zero emissions definition included embodied emissions of appliances over their full-life cycle. In response, a more appropriate requirement may be to require the top star rating or equivalent for appliances that need replacing, but this would be almost impossible to police.

Alternatively, or in addition to requirements of high energy efficiency ratings for appliances, limits can be set on the amount of user-related energy through a kWh/m2/year basis or a kWh/yr per occupant basis. Sartori et al (2010) makes recommendations for setting limits on electric energy consumption of appliances and other 'plug-loads', requiring optimum use of day-light and thus setting a limiting value on electric energy use for lighting, and setting limits on the amount of hot water consumption. The diversity of appliance use between building types and different climates makes setting these standards a complex task. It would also be very complex and resource intensive to regulate these standards. We do not recommend pursuit of such standards as part of zero carbon definitions in Australia at this time.

3.9.3 Cost

Switzerland's MINERGIE standard puts a requirement on cost, whereby costs to meet the MINERGIE Standard cannot exceed 10% of total building costs. The intention behind this requirement is to ensure feasibility and increased uptake of the standard. Whilst it is the only standard we have reviewed that includes a cost requirement, there has been large up-take of this voluntary standard as it sends out a positive and motivating message that low and zero energy buildings are affordable. However, on the other hand it does place significant limitations on the scope of initiatives that can be pursued to meet a net zero energy balance, alongside significantly discouraging and disabling some forms of innovation.

3.9.4 Sub metering

As noted in Section 3.2, one of the barriers to using monitoring to assess performance against a zero carbon base building definition is the availability of sub-metering to separate out base building energy use from total building energy use. While we are not aware of any definitions that establish particular metering requirements, it is certainly possible to specify particular metering conditions as part of a zero carbon definition. However, this would add to the cost of achieving zero carbon definitions and we recommend pursuing an approach based on modelled performance at this time.

3.9.5 Peak Demand Limits

Where a reduction in demand on the electricity grid is a policy objective, peak demand limits could be established as part of the conditional requirements associated with a zero carbon definition. Peak demand determines the scale of electricity infrastructure required to supply electricity. Growing peak demand in Australia is driving large investments in electricity infrastructure and contributing to rising electricity prices. Placing limits on peak demand addresses these problems and also provides greater certainty for network operators that need to supply new developments.

Peak limiting devices have been trialled in South Australia's Lochiel Park development. Particular appliances are switched off when electricity demand exceeds a predetermined limit. In return, trial participants receive reduced bills.

It is beyond the scope of this project to propose inclusion of peak demand limits as part of a zero carbon definition but this is certainly something that could be considered for particular regulatory or voluntary initiatives.

3.9.6 Recommendation

We recommend adoption of conditional requirements for energy efficiency and emission reduction options in the standard definition of a zero carbon building, as discussed in Section 3.9. Other conditional requirements could be added as appropriate for particular initiatives. In particular, it is important to ensure that a move to zero carbon buildings does not compromise comfort levels and conditional requirements related to comfort should be considered as part of specific initiatives.

4 SUMMARY OF RECOMMENDATIONS

It is clear from this review that there is great diversity in definitions adopted to help drive the delivery of low, zero or positive impact buildings. There is undoubtedly too much diversity and greater consistency across definitions would be valuable to reduce confusion. However, it is also important to point out that some of the diversity serves a purpose; a single zero impact definition will not meet all needs. Different developers will want to push further, including more of the building life cycle than others. Different sectors and building types have different challenges and opportunities, requiring flexibility in implementation.

Our recommendations seek to provide a single, standard definition of a zero carbon building as a baseline, while also providing consistent language that stakeholders can use when going beyond this basic definition. Based on our analysis of the elements of existing definitions, some recommendations apply across definitions:

- The primary metric for the definition should be greenhouse gas emissions, or zero carbon, expressed as kg CO_2-e/m^2/yr
- Only Scope 1 and 2 emissions should be included
- Compliance with the definition should be based on modelled and/or monitored performance over a year
- The definition should be a net zero carbon definition, allowing (but not requiring) grid connection
- The definition itself does not need to be varied to allow for different sectors and building types but different standards will need to be established across different sectors and building types when implementing the definition
- In implementing a definition, additional standards should be established for energy efficiency, use of on-site energy and possibly for comfort levels.

The main remaining source of variation is the coverage of the building life cycle and it is here that we believe some guiding language would be valuable. We recommend the following standard definition for zero carbon buildings:

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*
- *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 CO_2-e/m^2/yr.*

This standard definition applies to building emissions and would be an appropriate starting point for voluntary or regulatory initiatives to deliver zero carbon buildings. However, some developers will always want to push further and voluntary and regulatory initiatives will evolve over time. Therefore, we propose a consistent terminology in **Table 3** for describing variations from the standard definition.

Table 3: Proposed variations in terminology.

Variation	Terminology
Standard definition	Zero carbon building
Include occupant emissions	Zero carbon occupied building
Include embodied emissions	Zero carbon embodied building
Include all emission sources in the building life cycle	Zero carbon life-cycle building
No grid connection	Autonomous zero carbon building
Achieves less than zero emissions	Carbon positive building (or carbon positive occupied building etc.)

The standard definition is suitable for use in regulatory and voluntary initiatives but simpler language may be appropriate to communicate the definition to the marketplace. Some possible market-friendly language is as follows:

> *If operated as designed, the only greenhouse gas emissions from this home will be from the appliances and equipment that you bring with you when you move in. There will be no emissions from running the built-in heating and cooling, water heating, lights, stovetop and oven.*

The list of appliances in the second sentence could be modified based on final decisions on which end uses to include in definitions for specific initiatives.

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APPENDIX A: LIST OF SOURCES

Projects and Initiatives

Project or initiative	Website
2030 Challenge	http://www.architecture2030.org/2030_challenge/the_2030_challenge
Australian Zero Emission House Project	http://www.auszeh.org.au/
Carbon Neutral Program (Low Carbon Australia)	http://www.lowcarbonaustralia.com.au/cnprogram
Carbon Neutral Seattle	http://carbonneutral.seattle.gov/
Climate Positive (Clinton Climate Initiative)	http://www.clintonfoundation.org/what-we-do/clinton-climate-initiative/cities/climate-positive
European Directive on the Energy Performance of Buildings	http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm
MINERGIE	http://www.minergie.ch/
National Carbon Offset Standard	http://www.climatechange.gov.au/government/initiatives/national-carbon-offset-standard.aspx
Net Zero Energy Home Coalition	http://www.netzeroenergyhome.ca/
One Planet Living	http://www.oneplanetliving.org/index.html
Passivhaus Standard	http://www.passivhaus.org.uk/
R-2000 Standard (Canada)	http://oee.nrcan.gc.ca/residential/personal/new-homes/r-2000/standard/standard.cfm
UK Code for Sustainable Homes	http://www.communities.gov.uk/publications/planningandbuilding/codeguide
Zero Emission Neighbourhoods	http://www.resourcesmart.vic.gov.au/for_businesses/rebates_and_grants_3938.html

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Rating Tools

Rating tool	Website
EnerGuide (Canada)	http://oee.nrcan.gc.ca/energuide/home.cfm
Green Star	http://www.gbca.org.au/green-star/
Home Energy Rating System (HERS), US	http://www.resnet.us/home-energy-ratings
NABERS	http://www.nabers.com.au/
NatHERS	http://www.nathers.gov.au/

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