LOW CARBON LIVING CRC

Adelaide Living Laboratory

Value Proposition: Low Carbon Housing Policy

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Disclaimer

Peer Review Statement

This report has been peer reviewed by members of the Adelaide Living Laboratory Project Leaders Group.

Contents

Acronyms

BCA	Building Code of Australia, a part of the National Construction Code of Australia
CFL	Compact fluorescent lamp
CGE	Computable general equilibrium model
CPI	Consumer price index
CRC-LCL	Cooperative Research Centre for Low Carbon Living
GDP	Gross domestic product
GST	Goods and services tax
LED	Light emitting diode
NatHERS	Nationwide House Energy Rating Scheme
NPV	Net present value
PV	Photovoltaics
SA	South Australia
STC	Small-scale technology certificates

Executive Summary

Value proposition for low carbon living

The value proposition for low carbon living is defined as the articulation of the measurable value an organisation or individual will receive from the experience; where the end value equates to the perceived benefits minus perceived costs. This means that the value of low carbon living is unique to the perspective of the investor, and the set of benefits and costs included in the economic equation relate only to those likely to be perceived by the investor. For this study the investor is defined as the Government responsible for the policy requiring homes to be specifically designed for low carbon living.

The Government experience

This report 'Value Proposition: Low Carbon Housing Policy', the third in the series released by Adelaide Living Laboratory Theme 4, systematically presents a framework for which benefits and costs are perceived by the State Government investor. The research findings extend global knowledge of the value of low carbon living to the Government investor, particularly by incorporating industry learning factors, applying actual energy use evidence inclusive of rebound impacts, and including peak demand network benefits.

This report finds clear evidence there are multiple benefits associated with a low carbon living housing policy of mandating net zero energy homes. The Government investor would expect to achieve multiple policy outcomes across areas as diverse as health and wellbeing, productivity, energy, as well as the public budget. From a macro-economic perspective, although many impacts were not able to be monetised with sufficient confidence, the Government investor will experience a net increase in local employment, downward pressure on energy prices, and increased economic activity within a more efficient economy better able to respond to world energy price increases.

This report concludes that the value proposition of low carbon living is overwhelmingly positive to the South Australian Government with a conservative NPV of $1.31 billion for a 10 year policy action, and a benefit/cost ratio of 2.42. The empirical evidence demonstrates that low carbon living will provide many benefits including improved energy efficiency, energy network infrastructure savings, improved human health and wellbeing, carbon emission reductions, and benefits from increased social capital. The benefits far outweigh the costs associated with creating low carbon housing.

The report highlights the importance of two factors: (a) industry learning; and (b) the discount rate. As the housing industry adopts new technologies and practices, increases low carbon building system production volumes, improves industrial processes, and develops skills and knowledge across the various building industry professions, the net economic benefits to the community increase. The value of future costs and benefits is greatly impacted by the rate of discount applied for policy analysis, and in light of the intergenerational impact of anthropogenic climate change, the 7% rate applied in this report should be considered a worst case scenario. Lower discount rates provide increased benefits from the proposed low carbon housing policy.

This report has highlighted a number of limitations to the empirical evidence, and further research designed to quantify the health and wellbeing benefits of low carbon living will be necessary to provide greater certainty to the result. Further evidence is also necessary to determine whether a similar low carbon living value proposition is experienced from regulating higher density residential buildings, and in other climates.

Given the limitations of the research, the value proposition for low carbon living from the perspective of Government as an investor is overwhelmingly positive in Australia's most populous warm temperate climate zone.

Background

The value proposition exercise is a part of the Adelaide Living Laboratory project funded by the CRC for Low Carbon Living (CRC-LCL), with the South Australia Government and Renewal SA as the key project partners.

CRC for Low Carbon Living

The CRC for Low Carbon Living (CRC-LCL) is a national research and innovation hub which seeks to enable a globally competitive Australian low carbon built environment sector. With a focus on collaborative innovation, the CRC-LCL brings together experts from industry, government and leading researchers to develop pathways to low carbon living.

CRC-LCL is designed to develop new social, technological and policy tools for facilitating the development of low carbon products and services to reduce greenhouse gas emissions in the built environment.

A key objective of the CRC-LCL is to help cut Australia's anthropogenic carbon emissions by a total of 10 mega tonnes by 2020.

Adelaide Living Laboratories

The four year Adelaide Living Laboratory venture is an action based research project drawing evidence from three key Adelaide development sites at Tonsley, Lochiel Park and Bowden. Each of these sites has been established to meet specific government policy objects, is physically created by the local building and construction industry and includes detailed monitoring by the University of South Australia.

The Adelaide Living Laboratory project utilises the expertise and skills of community, industry and university participants to undertake site-specific research to build a stronger evidence base supporting government policy and planning, and industry delivery. The unique program of research is designed to help build a better understanding of low carbon living.

Stage 1 of the Adelaide Living Laboratory project explores four research themes: (a) co-creation; (b) precinct tool validation and use; (c) energy demand management solutions; and, (d) the value proposition for investment in low carbon development.

Value proposition research

Low carbon living provides a value proposition to various stakeholder investors according to their experience, and is this is represented by the scale and scope of the value equation. From a development scale perspective investigations will be undertaken at single building/household level up to suburb scale development, with each level introducing new economic costs and benefits, and at each level the value proposition appeals to different stakeholders.

The CRC-LCL value proposition work program will develop a total of 8 value proposition experiences capturing a diverse range of impacts experienced by different stakeholders, with each change of scope and level of complexity realising the costs and benefits specific to each stakeholder type.

This third report draws on the initial Literature Review by determining the value proposition from the perspective of Government as an investor through the implementation of a low carbon housing building regulatory policy. Further reports describing the value proposition from other investor perspectives will be developed throughout the four year research exercise.

Introduction

The value proposition for low carbon living is the net of all benefits and costs perceived by the investor [1]. This means that the particular benefits and costs used to determine a value proposition are only those relevant to the particular investor. Different investors: say home buyers, home builders, estate developers and government regulators; each perceive the value of that investment according to slightly different sets of benefits and costs. For example, home buyers may value low operational energy costs and increased thermal comfort from low carbon homes, whereby the wider society, represented by the government, may value decreased energy infrastructure costs associated with lower energy use and reduced peak energy demand.

In simple terms the value proposition is the articulation of the measurable value an organisation or individual will get from the offering; where the end value equates to the perceived benefits minus perceived costs [1]. Benefits are the outcomes and experiences of value to the customer, and costs are the financial exposure and other factors (i.e. time, risk) that the customer must pay to receive the product. The value proposition is communicated quantitatively as a net present value (NPV) calculation, covering all monetised costs and benefits associated with the effective life of the experience – in this case the effective life of the low carbon housing policy. A key limitation is that not all costs and benefits can be accurately monetised and included where there is insufficient evidence to allocate a dollar value to that experience.

This report explores and quantifies the value proposition from the perspective of the State or Regional Government introducing a net zero energy housing regulatory standard [2] that facilitates low carbon housing. The experience of low carbon living applied in this report draws heavily on the experiences of the State Government in setting building and precinct performance standards at Lochiel Park in South Australia, but also draws on the published literature examined in the initial project report 'Value Proposition: Literature Review'.

In particular, this report explores a wide range of impacts described in detail in the International Energy Agency report *Capturing the Multiple Benefits of Energy Efficiency*, which systematically analysed health and wellbeing, productivity, energy and macro-economic impacts, as well as impacts on the public budget due to energy efficiency policy actions [3]. Figure 1 shows the key impacts covered by the International Energy Agency report.

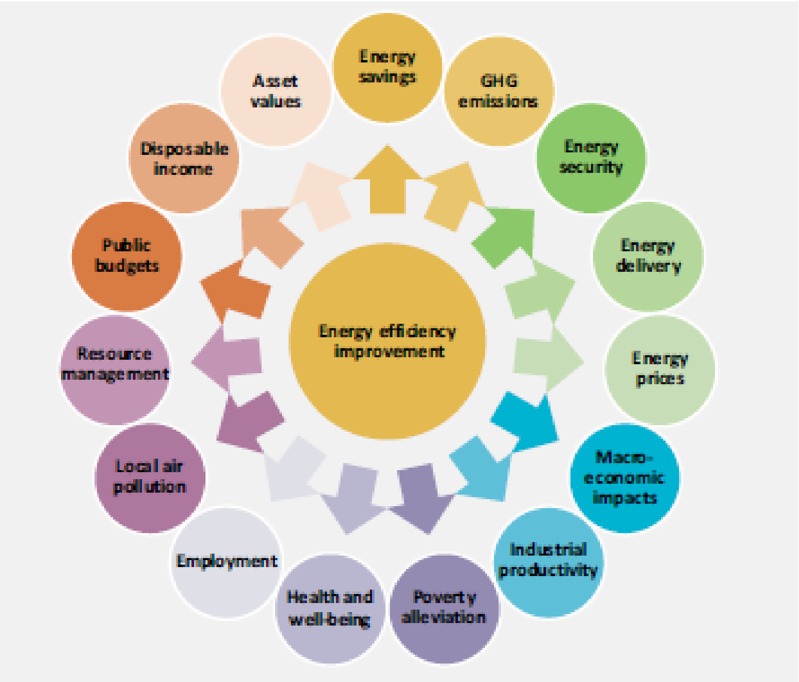

Figure 1: The multiple benefits of energy efficiency (IEA, 2014, p20)

In this value proposition scenario, State Government, being the instigator of the low carbon living policy, recognises and values a wide range of costs and benefits associated with the proposed policy change, although many of which may not directly impact the fiscal outcome of government budgets. Many impacts may be valued higher by government for their policy contribution rather than direct fiscal impact. For example: the reduction of energy wastage by householders is likely to improve the efficiency of energy supply, reduce air pollution and greenhouse gas emissions, and possibly improve local energy security, therefore supporting multiple government policy goals rather than providing direct fiscal benefits to government. Others impacts such as increased employment, the reduction of poverty, and higher disposable incomes may provide indirect fiscal benefits as well as meet policy goals; whilst some impacts such as health and wellbeing benefits may directly reduce the cost of government service provision.

The International Energy Agency report also noted in 2014 a lack of critical data and the absence of mature methodologies to measure the scope and scale of many impacts. Recently efforts to capture and quantify the multiple benefits of energy efficiency and low carbon living have increased with research presented from various countries including the United Kingdom, United States of America, Germany and France [4-9]. Unfortunately the problems associated with data and research methodologies remain to a large degree, and therefore the value proposition to government of many impacts cannot be costed in this report with sufficient confidence, but rather will be noted as an impact valued by government but not able to be quantified.

Some local evidence is available. The University of South Australia, in association with various government and industry organisations, has conducted an extensive program of research at the Lochiel Park Green Village over many years, and has published results describing many different experiences of low carbon living at the estate [2, 10-16]. The international literature expands on this knowledge by incorporating Government experiences from other low carbon houses, estates and climates.

The scope of experiences and impacts examined in this report is limited to the societal benefits and associated costs of low carbon living from the perspective of the Government investor in low carbon, relatively low density detached and semi-detached housing, and therefore explicitly excludes private benefits and associated costs that are experienced by other investors, such as the intrinsic benefits experienced by households from contributing to climate change action. Those benefits and costs experienced by other investors, or for other residential building types and densities, will be incorporated in separate value proposition reports.

The scope is also limited to those experiences related to living in a low carbon impact home and precinct, rather than other lifestyle experiences associated with food production, transport, waste management and other activities that occur or are mostly influenced by actions outside the dwelling or estate.

The following section articulates the key parameters and values incorporated within the value proposition NPV calculation, and frames the evidence supporting the value allocated to each economic impact. The economic analysis will explore the various impacts starting with construction cost and building industry impacts, then discussing energy network impacts, before moving to health and wellbeing and environmental impacts due to the policy change. Finally, the analysis will discuss various macro-economic impacts that may result from a more efficient economy.

Major parameters

A wide range of assumptions are required as inputs into the value proposition NPV calculation, covering issues such as the effective life of the policy action, the effective life of buildings, general price inflation, the rate of discount of future money, and the price escalation of energy.

As the empirical building energy performance evidence is climate specific and drawn from the Lochiel Park case study, the economic analysis in this study is limited to equivalent climates. Similarly, construction cost and energy pricing data is also, to a certain extent, location specific. For the purpose of this study the application of the policy will be illustrated from the perspective of the South Australian Government.

While the detailed economic analysis may be limited to new detached and semi-detached home construction in South Australia, the results throw light on the likely economic impacts of applying a similar housing energy standard in locations with a similar warm temperate climate such as Sydney and Perth, and higher density low carbon living. The application of a low carbon housing policy in other Australian locations with different climates such as cool temperate and sub-tropical climates will result in different energy and non-energy impacts, and different design strategies with associated costs and benefits. For locations with more extreme climates associated with significantly greater heating demand (i.e. cold temperate, alpine) or significantly greater cooling demand (i.e. tropical), the energy savings associated with low carbon housing are likely to be larger than the case study example with concomitant increased economic benefits.

And while the economic results may be different in other locations, many of the concepts applied in this study, such as industry learning rates and peak load benefits, are relevant in other Australian locations, and therefore the results from this study provide an insight into the experiences likely for other Australian state and territory governments.

General economic assumptions and factors

Between 8,600 and 9,500 new houses are constructed in South Australia each year, subject to market fluctuations [17]. The average total floor area for new homes in South Australia approximates 200m^2 [18, 19]. For the purpose of this study the rate of new construction is presumed to be 9,000 detached and semi-detached houses annually, with an average floor area for new homes of 200m^2.

The regulatory and construction cost environment is dynamic as societal expectations evolve and industry responds, therefore the economic evaluation of energy standards in the Building Code of Australia, National Construction Code is limited to a policy enforcement life of 10 years, although the impacts associated with that policy may continue beyond that period [20].

The Australian Bureau of Statistics suggests residential buildings have an effective life in excess of 50 years [21]; economists have argued that residential buildings have a design life of about 40 years, but are likely to be used for much longer [22]; and the Australian Government [23] suggests homes typically last for between 30 and 80 years. Previous building code change RIS publications have estimated the effective economic life of dwellings to be 40 years [24, 25], and for this study, homes are assumed to have an effective economic life of 40 years.

Discount and inflation rate

For NPV calculations the value of future costs and benefits is discounted. For policy initiatives the Australian Government's Office of Best Practice Regulation requires an annual real discount rate of 7%, with sensitivity analysis at 3 and 10% [26]. And although the Literature Review identified legitimate reasons to argue that factors including the irreversibility of climate change could justify using a lower discount rate that better supports temporal and intergenerational equity [27, 28], for the purpose of this report the average discount rate will be assumed to be 7%.

For the purpose of this report the annual rate of inflation will be set at the midpoint of the Reserve Bank of Australia's target band, being 2.5%.

Energy price and escalation rate

Since the privatisation of major public energy infrastructure in the mid to late 1990s, and the associated introduction of electricity generation and retail competition, electricity prices first fell and then rose compared to other goods and services as measured by the consumer price index (CPI). Since 2007, prices have increased against CPI, with rising network and distribution costs a major contributing factor [29]. But this rate of electricity price change may not be sustained in the immediate future, as residential *market offer* prices in South Australia are expected to decrease, on average, by 0.9% a year for the three years from 2012/13 to 2015/16 as a result of stabilising peak and average demand [30]. The Australian Energy Market Commission also argues that longer term predictions of price change are difficult due to the relatively large impact of government policies such as carbon taxes/trading, mandatory renewable energy targets, and photovoltaic feed-in tariffs. For the purpose of this report, electricity and gas prices will conservatively be assumed to increase only with the rate of inflation.

Retail domestic energy prices in South Australia, in 2014, range from $0.34 to $0.48 per kWh for electricity ($0.094 to $0.1333 per MJ), and $0.039 to $0.041 per MJ for natural gas. New tariffs, designed to incentivise action to address peak energy loads, are being introduced and are the subject of parallel investigation within the Adelaide Living Laboratory project. At this stage the effect of the new tariff rates is unknown, so for the purpose of this report the existing tariff rates will be applied, with purchased electricity priced at $0.0944 and gas $0.039 per MJ.

The price paid by electricity retailers for small-scale renewable energy has varied considerably over recent years as numerous 'feed-in' tariffs have been trialed to encourage the installation of domestic solar systems. Most recently government policy driven 'feed-in' tariffs have been removed and the market rate for renewable electricity generation has fallen. The minimum retailer payment for exported renewable electricity is set by the SA Government at $0.06 per kWh ($0.0167 per MJ) [31], which could be argued to be below the full economic value of that electricity if consideration is given to the timing of that solar generation and the relative match with peak demand. This minimum retailer figure will be used to calculate PV generation export income.

Construction cost and building industry impacts

Low carbon living is associated with changes to typical house designs; to the type, size and use of energy technologies; and potentially changes to maintenance schedules and regulatory compliance processes. For the purpose of this report low carbon living is based on the expected performance of a net zero energy home defined as: an energy efficient building that generates sufficient energy on-site over the course of a year to supply all expected on-site energy services for the building users [2]. Lochiel Park homes provide suitable examples of near net zero energy homes.

Although governments per se are not directly responsible for the cost of construction of all homes in their jurisdiction nor the energy used to provide the needs of building users, governments are responsible for the overall efficiency of the economy and therefore value the economic result of policy changes. In this case the value proposition to government of a change to net zero energy homes must recognise any increase and/or decrease in the cost of construction across the local economy. Later in the report we will discuss the macro-economic impacts related to changes in construction and building operating costs.

Building fabric

The Building Code of Australia sets the minimum building energy (thermal comfort) standard at NatHERS 6 Stars for housing, and meet the net zero energy housing standard a proposed move to NatHERS 7.5 Stars would be expected to increase construction costs. Studies have demonstrated that existing building designs at NatHERS 5 or 6 Star can be altered to achieve higher performance at a net reduction or trivial ($0-$500) increase in construction costs [32, 33]. These studies have found that a 6 Star home can be improved to just over 7 Stars at no cost increase, through simple changes to the glazing, insulation, and shading specifications; but to reach beyond around 7 Stars may need a step change to higher performance glazing such as insulating glass (i.e. double glazing) at a higher unit cost.

Local construction cost publications [34, 35] estimate the difference between single clear and double glazed windows to be between 169%~184%. For this report it is assumed that all living and bedroom windows will be upgraded, and for a typical 200m^2 home this represents changing 10 windows (max. 30m^2), although a smaller number of windows may be upgraded if combined with an improved shading strategy. For the purpose of this report, construction costs are assumed to increase by $3,000 to reflect specifying insulating glass for only those windows necessary to reach the higher energy standard or through a combination of glazing and shading changes; and a further $500 being the additional cost for higher specification insulation (e.g. R5.0 bulk ceiling batts).

Learning and logistics curves for building fabric costs range from 9 to 27%, with 18% being average [36, 37]. For the purpose of this report, the building fabric learning curve is assumed to be 18% per each doubling of production. The production volume of insulating glass and insulation systems for domestic construction is assumed to double every five years for the first 10 years following the establishment of the new energy standard, and as the building industry progressively adopts the cheaper and more available product.

Heating and cooling appliance

Studies have shown that when heating and cooling loads are greatly reduced, the system type and size needed to meet that demand can be changed with consequent cost reductions [38, 39]. Australian Government reports [24] noted that a 1kW reduction in cooling and heating capacity could save a building up to $200 in reduced heating and cooling plant, but discounted that saving by 50% to account for market rigidities. A simple internet market survey conducted in March 2014 [40] confirmed that each 1kW of additional reverse cycle air-conditioning capacity cost approximately $100.

For net zero energy homes, an increase from NatHERS 6 (96 MJ/m^2) to NatHERS 7.5 Stars (58 MJ/m^2 in this climate zone) is expected to reduce thermal comfort demand by at least a third [2]. The requisite reduction in heating and cooling plant for a 200m^2 home is conservatively estimated to be approximately 2kW. For the purpose of this report, the reduction in heating and cooling plant is assumed to be 2kW with an associated cost reduction of $200. Further savings due to the relatively low heating and cooling requirement are possible from the elimination of ducting, replaced by strategically located split system reverse cycle air-conditioning. This saving is not considered due to the current market attractiveness of ducted systems.

Lighting

A change to the proposed lighting density standard to 3W/m^2 [2] is not expected to increase lighting installation or maintenance costs. This is consistent with the approach used for the Building Code of Australia reduction to fixed lighting capacity [24]. Typical downlight products available in the Australian market to draw lower power include CFL (9~15 W) and LED units (9~14 W), with CFL products available for a similar or lower price than halogen dichroic (35/50 W) type products. Typically CFLs have a longer effective life than halogen products and have similar replacement costs. To achieve the proposed low carbon living standard, in some cases fewer units will be installed than would have previously been installed for the same floor area to meet the less efficient standard. Savings in replacement costs are also likely with a change from halogen to CFL lamps, but for the purpose of this report no change in replacement/maintenance costs are included because CFLs are not uncommon in new homes.

The LED alternative has an appreciably longer effective life but is relatively early in its product development lifecycle compared to mature halogen or CFL technology. The relative cost of LEDs is falling over time as the technology matures and the market transitions [41], and it is expected that LED lighting will become the industry standard. Lighting products are not manufactured in Australia and the domestic market has little impact on global production. For the purpose of this report CFL units will be used as the least cost product, with no associated industry learning rate.

Photovoltaics

The installed cost of photovoltaic systems in Australia has reduced rapidly over the past few decades and particularly in the last 5 years due to a combination of global production increases, retail competition and supply chain development. By December 2013 the average price of a 4 kWp system in Adelaide was $7396, and a 5 kWp system was $8,629 after consideration of GST and the value of STCs [42].

Recent literature has found that photovoltaics have averaged a learning discount of around 20% per doubling of production over a 20 year period once factors such as the fluctuating cost of silicon are considered [43], and PV modules are expected to reduce in cost by 67% between 2011 and 2020. de La Tour et al. (2013) also note that the effective life of PV modules will increase from 25 to 35 years during the same period, and Razykov et al. (2011) found that the worldwide market for PV is growing at between 35-40% annually [44].

For the purpose of this report the average net zero energy home (200m^2) will need a 4.75 kWp photovoltaic system [2] with an installed cost of $8321 (extrapolated from the December 2013 average cost). The photovoltaic panels are considered to have an effective life of 30 years. In this report, DC/AC inverters will have an effective life of 10 years and cost $2000 to replace before any associated learning rate. A learning rate of 20% will be applied for each doubling of worldwide production of PV related equipment, which is assumed to double every 5 years throughout the analysis period.

It should be noted that although the photovoltaic panels are replaced after 30 years and the replacement panels will continue to function after the effective life of the building, no electricity generation or residual capital value is allocated to the photovoltaics at the end of the effective life of the building. This is due to the relative uncertainty of the secondary market for photovoltaic panels towards the end of the analysis period.

Whilst there is a cost to the local economy associated with the commitment of economic resources to the renewable energy systems, from a government perspective that economic activity also creates additional jobs, certainly for system design and installation and potentially from manufacturing, satisfying other policy goals. Considering only the new jobs created from the design and installation of the photovoltaic systems, the policy is expected to increase employment by at least 72 fulltime equivalent positions (2 person days per system).

Water heating

The current South Australian building standard requires, for a typical new home, a solar or heat pump water heater of at least 26 STCs, or a gas system with a ghg intensity of no greater than 100g CO_2-e/MJ. The proposed net zero energy standard increases the minimum requirement to 40 STCs [2], and would mean a change in the typical system from a gas boosted solar storage product or an instantaneous gas system to an instantaneous gas boosted solar product. Estimator *Rawlinsons* nominate the cost difference between an instantaneous gas water heater and a solar system to be $2200 [34], or $1050 to add an instantaneous gas system (i.e. to an existing storage solar system). For the purpose of this report the average additional cost of changing to the 40 STC rated water heater will be $1750, and the assumed learning rate to be 18% per each doubling of production. The production volume of 40 STC rated water heaters is assumed to double every 5 years for the first 10 years of the proposed standard. A solar water heating system is considered to have an effective economic life of 15 years.

Maintenance

The change in construction materials and energy technologies due to the low carbon living standard will require increased insulation levels, changes in glazing type, water heater type and the addition of the solar energy system. None of the changes is expected to increase annual maintenance costs.

Industry compliance

Given that the existing regulatory processes, and the same energy performance assessment tools (i.e. NatHERS) will be used to determine compliance as required at the current BCA levels for thermal comfort, lighting and water heating; compliance costs are not expected to increase. The energy savings are drawn from monitored system performance at Lochiel Park due to the typical building industry compliance assessment processes. Improved compliance assessment is likely to increase costs, but is equally likely to improve operational energy savings [45].

The new standard includes the addition of a solar energy generation system, but compliance assessment processes have matured in an industry that has already installed over 1 million photovoltaic systems on Australian rooftops, and are included in published system installation costs. For the purpose of this report no additional compliance costs are expected.

Energy impacts

For low carbon living the proposed building energy standard creates direct energy savings due to the application of passive solar design strategies, changes to the lighting energy density, and an increase in the solar contribution to water heating. Additionally electricity will be generated by the on-site photovoltaic system to offset local energy use, thus substituting for electricity which would otherwise be purchased from the electricity network. From a government perspective, although it does not receive the direct financial benefit of any energy saving or substitution, the policy drivers include the provision of those benefits to constituents. Further macro-economic impacts are covered later in the report.

The following quantifies the expected savings and electricity generation and network benefits, and is determined from the building energy model discussed in the authors' associated publications [2, 40].

Thermal comfort

Assuming the average floor area of a new net zero energy home is 200m^2, the annual energy used for providing thermal comfort is reduced from 5920 MJ (6 NatHERS Star home) to 3550 MJ (7.5 NatHERS Star home), a saving of 2370 MJ in the Adelaide climate zone. This calculation is based on monitored homes in Lochiel Park and therefore incorporates any impact due to typical industry compliance issues.

Lighting

The reduction in lighting energy density from 5 W/m^2 to 3 W/m^2 is estimated from the building energy model to produce annual savings of 488 MJ.

Water heating

The increase in solar contribution and appliance efficiency due to a change from the current regulatory standard in South Australia (minimum 26 STC system) to the proposed minimum 40 STC system standard is expected to reduce annual energy use by 5,153 MJ based on the energy model [2]. Significantly larger energy savings in the range of 12,000~16,000 MJ [46] are likely to occur with a change from a non-solar system (i.e. 5 Star gas storage) to the proposed 40 STC solar system, but this option will not be included in the final economic analysis due to the lack of energy performance evidence for 5 Star gas storage systems available from monitored homes. The net energy saving from the change to a 40 STC system should be considered conservative and represents the worst case scenario of least energy savings.

Solar electricity generation

For a net zero energy home the electricity generated from the photovoltaic system should be equivalent in energy to that used to provide all energy services, but does not match the temporal profile of that energy use. This means that during any 24 hour period the building will be a net exporter to the grid at times and a net importer for other periods. Evidence from net zero energy homes at Lochiel Park shows that the amount of electricity exported from the photovoltaic systems represents approximately 50 to 60% of that generated, although this figure may be inflated by a relatively high feed-in tariff. For simplicity the percentage exported in this analysis is set at 50%. The photovoltaic system is expected to generate 23843 MJ per annum [2].

Network load reduction impacts

Electricity networks are a complex interaction between generation, transmission and distribution systems, and the demand for energy. The load on a particular electrical grid varies daily and seasonally, often peaking during periods of extreme climatic conditions, whilst simultaneously growing as new energy services are added to the system, and shrinking with improvements in the efficiency of energy services. The difference between managing daily demand on a mild day and the peak demand during extreme climatic conditions, such as a summer heatwave, represents a substantial investment in energy supply infrastructure which is used infrequently. In South Australia, data from the electrical network shows that one third of the required capacity is needed for 3% of the year [47], and the load difference between an extreme 38^{o}C day and an average 24^{o}C summer's day represents a 70% increase in electricity demand [48].

Recent evidence has demonstrated that residential rooftop PV, such as utilised in the proposed net zero energy housing standard, can lessen heatwave related peak electricity demand and associated blackouts, reducing the need for additional electricity supply infrastructure [49]. Energy demand monitoring at Lochiel Park indicates that the combination of thermally efficient building design, efficient air-conditioning technology and roof top photovoltaics, as utilised in low carbon homes, significantly reduces the amplitude and changes the timing of the peak electricity demand [11].

Research has shown that improvements in building energy efficiency, such as those expected from low carbon homes, reduce the cost of network energy supply and distribution, particularly costs associated with meeting peak demand [50]. Langham et al. (2010) calculated the annual rate of infrastructure savings per floor area of residential building per percentage of electrical energy efficiency improvement to be AUD$0.024. For an average 200m^2 home, each percentage improvement in electrical energy efficiency equates to an electrical network infrastructure saving of $4.80.

Given that the photovoltaic system required by the proposed standard generates more electricity than is used for household energy services during the daylight hours within periods of extreme network electricity demand, such as summer heatwaves, the percentage improvement could be considered as greater than (i.e. exporting) or equal to 100% during those hours. But household electricity demand continues outside of daylight hours, and the electrical energy efficiency for those periods will be relative to thermal efficiency gains and the efficiency of household appliances and lights.

For the purpose of this study, the average electrical efficiency gain shall be deemed to be 50%, and the value of the infrastructure saving for a 200m^2 home is $240 per annum. This is deliberately conservative.

Energy security

Energy security is defined by the International Energy Agency as "the uninterrupted physical availability of energy at a price which is affordable, while respecting environmental concerns" (IEA, 2014, p49). The proposed net zero energy housing standard will result in reduced demand which can improve the security of energy provision. Insufficient evidence was available to quantify the energy security impact of the policy change, so for the purpose of the NPV calculation in this report no economic cost or benefit is allocated.

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Non-energy economic impacts

Not all costs and benefits of net zero energy homes are associated with the construction of the building, or the energy used and generated by the building. Externalities related to the market perception of future benefits, the contribution of low carbon buildings to climate change mitigation policies, and potential improvements to human health and productivity are also possible additions to the value proposition NPV calculation. Where it is practical, these impacts have been monetised. The following examines the major impacts.

Carbon emission savings

Given the explicit carbon emission policy aspirations of all levels of government in Australia, reductions in emissions associated with low carbon living reduce the need and associated cost of alternative policy action.

The monetised value of future carbon emission savings related to the use of renewable energy systems (solar water heater and photovoltaic systems), in the form of STCs, is already incorporated into the cost of those technologies.

Carbon emission savings relating to the reduced demand for other energy services, particularly lighting and thermal comfort, can be monetised using the average value of emissions auctioned under the Australian Government's Direct Action Plan. Given the average greenhouse gas emission factor for electricity available in South Australia is 173 kg CO_2-e/GJ [51], the annual total energy saving offset is 2,858MJ, and the price of abatement due to the Australian Government's Direct Action Plan is expected to average $20/t CO_2-e, for the purpose of this report the average additional annual value of the carbon emission savings per house is assumed to be $10.06. As the first auction under the Direct Action Plan achieved an average estimated cost of abatement at $13.95/t CO_2-e not including government administration costs, this value of savings may be considered inflated, although subsequent auctions are expected to achieve higher average abatement costs.

Asset value benefits

The Literature Review noted that housing markets in many nations value improvements in a building's energy efficiency [52-55]. An Australian study found that the market valued each 0.5 NatHERS Star increase at 1.23% to 1.91% above the median house price [53]. The Australian study was conducted on homes in a cool temperate climate (Canberra) where total heating and cooling loads are relatively large compared to warm temperate climates such as Adelaide, and therefore it may be reasonable to expect the market to value energy efficiency higher than in warmer climates.

The key problem with the inclusion of asset value impacts in RIS calculations is that they occur only when the asset is presented to the market. In the case of housing there is no standard period before a house is offered to the market; therefore it is difficult to allocate the likely realisation of the benefit to a specific point in time. For the purpose of this analysis a relatively small market premium available on resale is applied as a discount to the construction cost (estimated $250,000) of 1%, resulting in a discount of $2500 available immediately on occupation. This is a conservative estimate of the likely market premium afforded homes of substantially higher energy efficiency, and a net zero operational energy balance. Where mandatory disclosure of energy performance on sale of property has been legislated, the market premium for improved energy efficiency will likely be substantially larger.

And although the Government investor is not directly involved in typical real estate transactions, with the exception of receiving stamp duty taxes, Governments are responsible for and value the benefit of efficient markets and the various energy efficiency, energy network and energy security benefits associated with improved building energy performance.

Health and productivity impacts

Building related thermal comfort has a strong relationship with human health and productivity which was explored in the Literature Review. The literature noted that thermally comfortable indoor conditions provide improved physical health, mental health and emotional well-being [56-58]. From the perspective of the Government investor, the economic effects relate to rates of mortality, hospital and ambulance demand, general practitioner and district nursing service demand, the effectiveness of pharmaceuticals, and even incidents of domestic violence, particularly during period associated with extreme climatic events such as heat waves.

Thermally comfortable homes provide both societal and private benefits. The international literature indicates that the societal value of non-energy benefits of thermally efficient homes, related to improvements in human health and productivity, could be considerably larger than the energy benefits [59-61]. An Australian study estimated the direct private economic benefit for a NatHERS change from 5 to 6 Stars was approximately $9.50 per household per annum [62], and given the thermal comfort improvement for the low carbon housing standard would be similar, the private benefit could be of similar value.

But given the difficulty of estimating the public value of non-energy related benefits of low carbon homes in this specific climate, for the purpose of this study the lower value, representing only the direct private benefit, will be used in the net present value calculation. This is deliberately conservative. Sensitivity analysis will highlight the potential impact if the public value is similar in magnitude to the value of energy savings.

Green building facades

The Literature Review noted that the creation of green infrastructure such as green roofs and walls can provide a range of public benefits including, but not limited to, stormwater management, air pollution reduction, reduction of heat island effect, reduction of building energy usage for thermal comfort, and increased biodiversity [63]. Green walls also provide acoustic benefits, privacy and possibly aesthetic benefits [64].

For the purpose of this report, green building facades are not considered necessary nor likely in the mass construction of low carbon homes, and therefore no economic cost or benefit is allocated.

Sense of community

The Literature Review noted that humans, in general, are social animals and benefit emotionally and physically from interpersonal relationships. The creation of social capital, enhanced by designing estates to encourage informal social interaction, can be linked to physical and mental health benefits [65-67]. The creation of social capital is intrinsic to the concept of low carbon living, where building and estate design encourages healthier, well connected and more resilient communities which are supportive of low carbon behaviours.

The literature provides no indication of the likely benefit of low carbon living social capital, and no new data collection was conducted into the value of social capital for this report. Therefore for the purpose of this report no value will be allocated to the benefit gained from an enhanced sense of community. This report recommends the Adelaide Living Laboratory project conduct further research into quantifying the value of social capital creation to all types of investors.

Macro-economic impacts

The change to a net zero energy housing policy provides additional economy-wide investment and cost reduction effects. The macro-economic benefits of low carbon living are likely to facilitate increased economic activity (as measured by gross domestic product [GDP]), higher local employment, advantageous price impacts and favourable trade balances [3].

The international evidence from econometric research into energy efficiency policies, including low carbon housing policies, has pointed to considerable positive impacts on employment and GDP [4], decreases in inflation, growth in GDP [68], and falls in energy prices [69].

The lack of local macro-economic evidence and modelling, and evidence specific to a net zero energy home policy, means that for the purpose of this report no additional economic cost or benefit will be allocated to macro-economic impacts. It should be noted that the benefits, which are likely to be significant, increase the value proposition of the policy to government. Further macro-economic research will be necessary to determine the scope and value of the likely benefits.

The additional economic activity related to higher value building materials and the additional renewable energy systems will have flow-on effects of increased taxation revenue, and similarly the increase in disposable incomes due to lower operational energy costs will have a net positive effect on government tax revenues. Due to the complexity of tax revenue redistribution between Federal and State levels of government in Australia, the calculation of the value of additional tax revenues is beyond the scope of the project.

Although the report is unable to calculate with sufficient confidence the macro-economic impact of a transition to net zero energy homes, there is sufficient evidence to suggest that the Government will achieve and value a net increase in local employment, downward pressure on energy prices, and increased economic activity within a more efficient economy better able to respond to world energy price increases.

The value proposition to Government

Government policy is assessed from a societal perspective, with the value proposition of low carbon living to Government assessed by the net of the private and public costs and benefits associated with the creation and operation of low carbon homes. This section examines the monetised economic impact of low carbon living from the perspective of Government as the regulator of low carbon housing, thus incorporating benefits that are bestowed on the wider community, such as network peak demand impacts and health infrastructure provision savings and workplace productivity benefits.

But we should also be careful to note that many of the impacts experienced may not readily be monetised, or that uncertainty in allocating a numerical figure results in the conservative scenario of allocating little or no quantified economic impact for some stakeholder experiences. These impacts are real and add or detract from the monetised economic outcome described below.

NPV equation

The net present value (NPV) equation used for the value proposition analysis is represented by:

$$\mathrm{NPV}(i) = \sum_{t=0}^{N} \frac{(\mathrm{benefits} - \mathrm{costs})_t}{(1+i)^t}$$

where

N = the effective life of the action

t = the time of the cashflow

i = the discount rate

benefits = positive Government investor experiences

costs = negative Government investor experiences

Net economic impacts

Given the caveat that some experiences are difficult to monetise with a degree of confidence, applying the assumptions and values described earlier in the report, the NPV calculation is overwhelmingly positive.

Table 1: Economic results for proposed low carbon house standard

Benefit	$2,226m
Cost	$919m
Net Present Value	$1,307m
Benefit/Cost Ratio	2.42

Table 1 shows the present value of all monetised benefits and costs associated with low carbon living, based on a discount rate of 7%, for the 10 year effective life of the proposed policy. The benefit/cost ratio is 2.42 and NPV is $1.31 billion demonstrating that the Government investor will receive a substantial net benefit from regulating low carbon housing, even without considering the likely significant macro-economic benefits.

Whilst the majority of the economic benefit is due to improved energy efficiency and the electricity generated by the photovoltaic system, strong flows of benefits also stem from energy network savings. Smaller but valuable flows relate to the health and wellbeing impacts of improved thermal comfort, although these benefits are likely to be significantly underestimated. The majority of costs relate to the use of renewable energy technologies, with a smaller impact from improved levels of building thermal efficiency.

The NPV result is sensitive to the discount rate applied, but remains strongly positive with a benefit/cost ratio of 1.95 at a relatively high discount rate of 10%, and achieves a benefit/cost ratio of 3.49 at a 3% discount rate. Sensitivity analysis shows that without the various indirect benefits the benefit/cost ratio at the 7% discount rate is 1.96 demonstrating that the direct energy benefits are substantially greater than the net costs of the proposed standard. If the non-energy (i.e. health and productivity) benefits were equivalent to the value of the thermal comfort related energy savings, the net value increases to $1.52 billion with the benefit/cost ratio increasing to 2.65.

The annual flow of costs and benefits (see Figure 2) shows that the present value of the additional construction costs is initially higher than the present value benefits from energy savings, electricity generation and other factors. By year 5 the annual benefits from the accumulation of new homes become larger than the additional costs associated with the low carbon housing standard. After the 10 year policy period new homes cease to be added and the remaining costs relate to the replacement of water heaters, DC/AC inverters and photovoltaic panels at the end of their respective economic life.

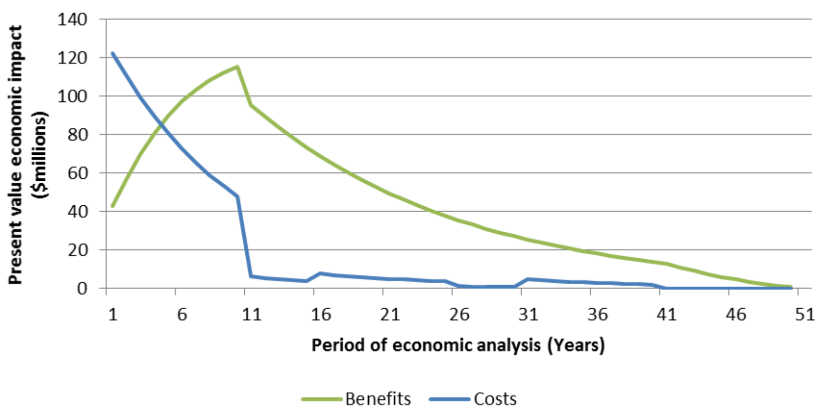

Figure 2: Flow of economic costs and benefits for proposed standard

Figure 2 graphically presents the relative monetised economic flows after taking into account inflation, energy price escalation, discount rates and industry learning rates. In the graph the initial increased construction cost is followed by periodic product replacement costs, whilst the continuous benefit stream (note the impact of discounting) is experienced by society for the life of all buildings constructed under the low carbon housing policy. Whilst the impact of each home extends to their 40 year effective life, the policy is implemented for 10 years resulting in some benefits being received by the Government investor 50 years after the policy introduction.

Limitations of the research

The time and resource budget for the value proposition exercise of the Adelaide Living Laboratory project did not facilitate additional primary data collection to determine the economic value for many low carbon living experiences. In particular, the perceived benefits relating to improved health and wellbeing associated with increased thermal comfort experiences, and the benefits associated with the creation of social capital were limited by the available data. Where possible impact estimates were drawn from the literature, but further research is necessary to provide greater certainty around these benefits.

Similarly, the constraints of the project did not allow the detailed exploration of macro-economic impacts using energy-economy-environment computable general equilibrium (CGE) model of the South Australian economy. The literature offers some insight into the likely impacts, but estimates of likely local impacts cannot be included with sufficient confidence.

The research draws heavily on the value proposition experience of low carbon living at Lochiel Park, and further research exploring the benefits and costs associated with different built form (i.e. apartments) would facilitate a better understanding of low carbon living in higher urban density scenarios. This will be the subject of subsequent value proposition studies within the Adelaide Living Laboratory project, with specific data collection opportunities at Bowden and Tonsley urban developments.

Low carbon living extends beyond the building or estate boundary. For example, transport and food production activities relate directly to the net carbon emission impact of residential estates. This report has been limited to building energy related impacts rather than extend to other aspects of low carbon living, including impacts associated with water efficiency, water harvesting and water recycling. This can be seen as an artificial construct, and it is highly likely that Government as an investor in low carbon living may not differentiate between the various carbon impacts, but rather value the full gamut as a complete low carbon experience.

The research draws mostly on evidence from low carbon living in warm temperate climates such as experienced in Adelaide, Sydney and Perth. Further research is necessary to understand the value proposition experience for those investors in other climates, where additional construction costs and technology choices, and the energy and thermal comfort impacts are likely to be very different.

Conclusion

From a government perspective there are multiple benefits associated with a low carbon living policy that mandates a net zero energy housing standard. The Government investor would expect to achieve multiple policy outcomes across areas as diverse as health and wellbeing, productivity, energy, and macro-economic impacts; as well as impacts on the public budget.

The value proposition of regulating low carbon housing is overwhelmingly positive with the Government investor experiencing a NPV benefit of $1.31 billion as a result of the policy, with a benefit/cost ratio of 2.42.

Sensitivity analysis highlights that even applying an unusually high discount rate or by removing a range of indirect benefits, the value proposition remains positive to Government. In simple terms, the South Australian community substantially benefits from requiring all new homes to meet a net zero energy building standard.

The experience of the Government investor documented in this report demonstrates that low carbon living provides a range of benefits including lower energy bills, energy network infrastructure savings, increased levels of thermal comfort, improved health and wellbeing, carbon emission reductions, and benefits from increased social capital. Where those experiences can be monetised with reasonable confidence, the net societal economic impact is overwhelmingly positive.

The additional construction costs and subsequent technology replacement costs are quickly overtaken by a steady stream of economic benefits received by the local economy. By Year 5 of the low carbon housing policy action with a 50 year ongoing impact, the benefits outweigh the costs.

And although this report is unable to monetise with sufficient confidence the macro-economic impact of a transition to net zero energy homes, there is sufficient evidence to suggest that the Government investor will experience a net increase in local employment, downward pressure on energy prices, and increased economic activity within a more efficient economy better able to respond to world energy price increases.

This report notes important limitations to the data, particularly those costs and benefits associated with health and wellbeing experiences, and the potential benefits of increased social capital. Further research is necessary to establish greater certainty regarding assigned values where empirical evidence was unavailable, and to understand the experiences of investing in higher density low carbon living, and the experience in other climates.

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