Adelaide Living Laboratory

Value Proposition: Householder Experience

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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
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 are related only to those likely to be perceived by the investor. For this study the investor is defined as the owner occupier household of a home specifically designed for low carbon living.

The householder experience

The first report released by Adelaide Living Laboratory Theme 4 was 'Value Proposition: Literature Review' which described a wide range of private and public benefits and costs associated with the experience of low carbon living. This second report 'Value Proposition: Householder Experience' builds upon that literature and extends our knowledge by quantifying the key benefits and costs associated with the householder experience of low carbon living. This report systematically presents a framework for which benefits and costs are perceived by the householder investor and assigns a value to that experience, and extends global knowledge by expanding the range of impacts covered. In particular, this report increases global knowledge by incorporating industry learning factors, applying actual energy use evidence inclusive of rebound impacts, and includes some health and wellbeing householder experiences.

This report concludes that the value proposition of low carbon living is overwhelmingly positive to owner occupier households with a conservative NPV of $24,935 if the home was built in Year 1 of a policy change to net zero energy housing, and with larger net benefits received for homes constructed in subsequent years. The empirical evidence describing the experience of householder investors demonstrates that low carbon living provides many benefits including lower energy bills, increased levels of thermal comfort, improved health and wellbeing, intrinsic values associated with taking climate change action, and benefits from increased social capital. Many of the impacts are externalities not typically incorporated in policy analysis or the business case, yet they are real and valued experiences to householders. The benefits far outweigh the costs associated with creating a low energy use, thermally comfortable home environment for low carbon living.

The report notes the importance of industry learning. 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 cost of creating low carbon homes reduces and net benefits to the householder investor improve. But irrespective of whether the home is created in the first or subsequent years along the industry learning curve, low carbon living provides the householder investor with a substantial net economic benefit over the assumed year life of the building.

This report has highlighted a number of limitations to the empirical evidence, particularly those related to the availability of reliable data for some householder experiences, and further research designed to quantify many of the intrinsic 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 by those in medium and higher density estates, and in other climates.

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

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.

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 objectives, is physically created by the local building and construction industry, and incorporates data collection and analysis 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 value proposition work program is designed to develop a total of 8 value proposition experiences capturing a diverse range of impacts from building energy savings to human health benefits to transport to food system to biodiversity to social sustainability impacts, with each change of scope and level of complexity realising benefits to different stakeholders.

This second report draws on the initial Literature Review by determining the value proposition from the perspective of household investors (home owners). Further reports describing the value proposition from other investor perspectives will be developed throughout the four year research exercise. In particular, value proposition research will be conducted in the Bowden and Tonsley urban developments to better understand the value of higher density low carbon living.

Introduction

The value of 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 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 a low carbon impact home. 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 owner occupier of a low carbon impact residential building. The experience of low carbon living applied in this report draws heavily on the experiences of households at Lochiel Park in South Australia, but also on the published literature examined in the initial project report 'Value Proposition: Literature Review'.

The University of South Australia, with the support of 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 [2-9]. The Literature Review expands on this knowledge by describing householder experiences in other low carbon estates, or in individual low energy and low carbon impact homes.

The scope of experiences and impacts examined in this report is limited to the private benefits and associated costs of low carbon living from the perspective of the householder investor, and therefore explicitly excludes societal benefits and associated costs such as impacts to energy networks due to reductions in peak energy demand or lower health costs associated with improved thermal comfort reducing the need for hospital visits. Those societal benefits and costs will be experienced by other investor types such as government policy makers, and will be incorporated in future value proposition reports.

The scope is also limited to those householder 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 mainly outside the dwelling or estate. The scope is also limited to carbon emission impacts rather than broader environmental sustainability issues, and therefore water related impacts are limited to the energy used to meet hot water demand, although recognising that the provision of potable water has a carbon emission impact which is outside the scope of this report.

The following section articulates the key parameters and values incorporated within the NPV calculation, and frames the evidence supporting the value allocated to each.

Major parameters

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

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% [10]. 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 [11, 12]. These discount rates are representative of social impacts rather than private impacts.

From the householder perspective, the likely interest cost of borrowing for property investments (mortgage rate) represents an appropriate discount rate. Borrowing rates fluctuate widely according to the state of the local economy, with the cost of borrowing reflecting the Reserve Bank of Australia's cash rate plus the cost of institutional lending. For the purpose of this report the property investment borrowing rate will be assumed to be 5% representing the average over the previous 5 years.

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 [13]. 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 [14]. 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 [14].

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. For the purpose of this report purchased electricity will be 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) [15], 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 and equipment costs and savings

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 [4]. Lochiel Park homes provide suitable examples of near net zero energy homes.

Building fabric

The Building Code of Australia sets the minimum building energy (thermal comfort) standard at NatHERS 6 Stars for housing, and 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 [16, 17]. 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 [18, 19] 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 [20, 21]. 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 [22, 23]. 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 [25] confirmed that each 1kW of additional reverse cycle air-conditioning capacity cost approximately $100.

An increase from NatHERS 6 (96 MJ/m^2) to NatHERS 7.5 Stars (58 MJ/m^2) is expected to reduce thermal comfort demand by at least a third. 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 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 [26], 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 [27].

Recent literature has found that photovoltaics have averaged a learning discount of around 20% over a 20 year period once factors such as the fluctuating cost of silicon are considered [28], with predictions that PV modules will 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. Razykov et al. (2011) found that the worldwide market for PV is growing at between 35-40% [29].

For the purpose of this report the average new home (200m^2) will need a 4.75 kWp photovoltaic system 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.

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 low carbon living standard increases the minimum to 40 STCs, 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 [18], 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 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. Electricity generated by the on-site photovoltaic system offsets household energy use, thus substituting for electricity which would otherwise be purchased from the local electricity network. The following quantifies the expected savings and electricity generation benefits, and is determined from the building energy model discussed in the authors' associated publications [4, 25].

Thermal comfort

Assuming the average floor area of a new 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 [4].

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 [4].

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. Significantly larger energy savings in the range of 12,000~16,000 MJ [30] 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. Sensitivity analysis will be conducted for the non-solar product related change, 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

The photovoltaic system provides sufficient electricity to meet all energy services, but does not match the temporal profile of that energy use. During any 24 hour period the household will be a net exporter to the grid at times and a net importer for other periods. Evidence from those Lochiel Park homes that are near net zero energy in performance shows that the amount of electricity exported from the photovoltaic systems represents around 50 to 60% of that generated, although this figure may be inflated by a relatively high feed-in tariff utilised by many households, but no longer available. For simplicity the percentage exported in this analysis is set at 50%. The photovoltaic system is expected to generate 23843 MJ per annum [4].

Peak load reduction impacts

Peak energy demand reductions provide public benefits through the reduced need for additional energy network and generation infrastructure, and potentially can provide direct private benefits to the household where local energy infrastructure has been scaled back to meet new demand profiles. No evidence was available that energy network providers had reduced local infrastructure standards to match the lower likely peak demand, and therefore no benefit is assigned. Further research may allow this additional benefit to be incorporated in future value proposition analysis..

Non-energy economic impacts

Not all costs and benefits of net zero carbon 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 experience of households with low carbon living or potential changes to human health and productivity are also possible additions to the value proposition NPV calculation where it is practical to monetise those impacts. The following examines each major impact.

Carbon emission savings

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, are 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 traded in the Australian market. Given the uncertainty regarding carbon emission trading in Australia, for the purpose of this report no value will be allocated to emission savings caused by reduced energy service demand.

Taking action to address anthropogenic climate change through low carbon living provides an intrinsic value to households. This householder experience of a positive contribution to collective climate change action is evident in the interview responses from Lochiel Park residents [5]. Economic models have been established to extract the economic value gained from altruistic and pro-environmental behaviours [31, 32]. Techniques such as 'willingness-to-pay' for particular actions allow the monetisation of intrinsic values [33, 34]. Carbon offset programs further demonstrate that some consumers place a value on taking action to address climate change [35, 36]. As no new research to determine the average value of taking action through low carbon living has been conducted for this report, the nominal value will be determined by the annual value of emission savings expected in the open market. Given the average greenhouse gas emission factor for electricity available in South Australia is 173 kg CO_2-e/GJ [37], the annual total energy offset is 23,843MJ, 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 annual intrinsic value of taking action is assumed to be $84.

Asset value benefits

The Literature Review noted that housing markets in many nations value improvements in a building's energy efficiency [38-41]. 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 [39]. 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 to the homeowner 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.

Thermal comfort related impacts

Thermal comfort is a primary want and need for humans. Human thermal comfort is defined as the "condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation" [42]. Thermal comfort is also a social construct reflecting the beliefs, values, expectations and aspirations of households, with demand for comfort increasing dramatically over the past few decades [43].

The value of thermal comfort reaches beyond the simple calculation of energy costs to maintain the desired level of comfort. Building related thermal comfort has a strong relationship with human health which was explored in the Literature Review, although much of the benefit was social rather than private. The literature noted that the householder experience of thermal comfort provides improved physical health, mental health and emotional well-being, with an Australian study estimating the direct private economic benefit for a NatHERS change from 5 to 6 Stars was approximately $9.50 per household per annum [44]. Given the thermal comfort improvement for the low carbon housing standard would be similar, the direct benefit would be of similar value.

The value proposition of low carbon living includes the householders perceived benefits of year round improved thermal comfort, an experience highlighted and valued by many Lochiel Park households during a series of semi structured interviews [5]. As no new data collection was conducted into the intrinsic value of thermal comfort for this report, the nominal value will be determined by the annual value of the thermal comfort related energy savings. For the purpose of this report the combined direct and intrinsic private annual economic benefit of improved thermal comfort shall be $233.

Green building facades

The Literature Review noted that the creation of green infrastructure such as green roofs and walls can provide a range of 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 [45]. Green walls also provide acoustic benefits, privacy and possibly aesthetic benefits [46].

And whilst the majority of the benefits are likely to be social rather than private, such as air quality improvement, carbon reduction, habitat creation, aesthetic impact, and urban heat island mitigation [47], some private benefits are expected. 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 [48-50]. The creation of social capital is intrinsic to the concept of low carbon living, where building and estate design encourages healthier and more vibrant communities which are supportive of low carbon behaviours.

The literature provides no indication of the private benefit of low carbon living social capital, and no new data collection was conducted into the intrinsic value of social capital for this report. Therefore for the purpose of this report no value will be allocated to the householder experience 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 household investors and estate developer investors.

The value proposition to owner occupier households

Whilst government policy is assessed from a societal perspective, the value proposition of low carbon living to the householder investor is assessed by the net of the private costs and benefits experienced by that household. This section examines the monetised economic impact of low carbon living from the perspective of the home owner/operator, thus removing benefits that are bestowed on the wider community, such as network peak demand impacts or health infrastructure provision savings or workplace productivity benefits.

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

The analysis also examines the private economic impacts at two construction points to illustrate the impact of expected building industry learning due to increased production volumes, improved industrial processes, and increased industry skills and knowledge. The first construction point is in Year 1, before new learning opportunities substantially impact the costs of building products, design strategies or construction processes; and the second point illustrates the economic impact if the home was constructed in Year 10 at the end of decade long low carbon living policy lifecycle, whereby industry has responded through innovation, skill development, improved production processes and various other learning opportunities.

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 householder investor experiences

costs = negative householder investor experiences

Private economic impacts from Year 1 construction

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

Table 1: Private economic impacts from Year 1 construction

Benefit	$41,355
Cost	$16,420
Net Present Value	$24,935
Benefit/Cost Ratio	2.52

Table 1 shows the present value of the private benefits and costs associated with low carbon living, based on a discount (mortgage interest) rate of 5%, if the home was constructed in the first year of the proposed policy. The benefit/cost ratio is 2.52 and NPV is $24,935 demonstrating that the household investor will receive a relatively large net benefit from low carbon living over the effective life of the home.

Whilst much of the economic benefit is due to the value of electricity generated by the photovoltaic system, strong flows of benefits are also linked to householders valuing improved levels of thermal comfort, and lower energy service demands. The majority of costs are due to the application of renewable energy technologies, with a smaller impact from improved levels of building thermal efficiency.

The flow of costs and benefits throughout the building's effective life find that the initial additional construction costs are covered within the first 8 years of low carbon living, with economic benefits dominated by the substitution of free solar energy for the otherwise high cost of purchased energy. The periodic additional costs (see Figure 1) due to the replacement of various systems is swamped by the long flow of benefits due to operational energy savings, ongoing thermal comfort and health benefits, and solar electricity generation.

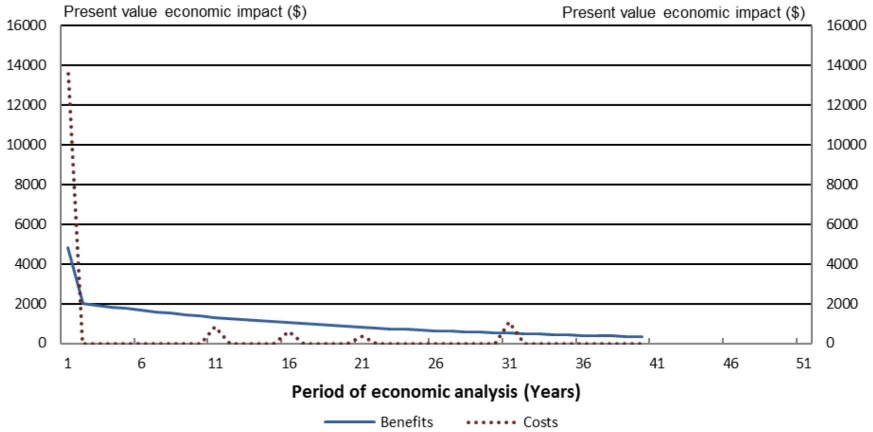

Figure 1: Private economic impacts from Year 1 construction

Figure 1 graphically presents the relative monetised economic flows throughout the 40 year effective life of the building 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 the householder investor for the life of the building.

Private economic impacts from Year 10 construction

If construction was completed in the 10th year of industry's experience of providing low carbon homes, including a 10 year period of building product learning process, the benefit/cost ratio increases to 3.54 (see **Table 2**).

Table 2: Private economic impacts from Year 10 construction

Benefit	$52,040
Cost	$14,709
Net Present Value	$37,331
Benefit/Cost Ratio	3.54

Whilst the benefit stream is predominantly impacted by inflation, the additional construction cost even after inflation has decreased, reflecting the benefits associated with policy stimulated increased building system production volumes, improved industrial processes, and the development of skills and knowledge for the various building industry professions.

Overall, the associated flow of benefits due to operational energy savings, ongoing thermal comfort and health benefits, and solar electricity generation, remains strong whilst the cost to household investors to achieve low carbon living is relatively lower than those experienced in Year 1 construction. This is typical of industrial change, whereby early adopters stimulate change whilst those who enter the market when technologies mature and competition increases are likely to receive greater net benefits.

Limitations of the research

The time and resource budget for the value proposition exercise did not facilitate additional primary data collection to determine the economic value for many low carbon living householder experiences. In particular, the determination of perceived benefits relating to the householder's contribution to climate change action, increased thermal comfort experiences and 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.

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.

Low carbon living extends beyond the building or estate boundary. For example, transport activities relate directly to the experience of the household and their net carbon emission impact. This report has been limited to building and estate built form energy related impacts rather than extend to other aspects of low carbon living, including experiences of water efficiency, water harvesting and water recycling. Similarly, the experience of food production of low carbon living have not been incorporated, even those related to food production within the property or estate boundary. This can be seen as an artificial construct, and it is highly likely that household investors do not differentiate between the various low carbon living experiences, 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 household investors in cool temperate and hot humid climates, where additional construction costs and technology choices, and the energy and thermal comfort impacts are likely to be very different.

Summary

The value proposition of low carbon living for detached homes is overwhelmingly positive with the householder investor experiencing a NPV benefit of $24,935 for homes constructed in Year 1 of the policy, and subsequent constructions providing householder investors with increased benefits.

The experience of the householder investor documented in this report demonstrates that low carbon living provides many benefits including lower energy bills, increased levels of thermal comfort, improved health and wellbeing, intrinsic positive feelings associated with climate change action, and benefits from increased social capital. Where those experiences can be monetised with reasonable confidence, the net private impact is overwhelmingly positive to householder investors.

Whether the home is created in the first or the last year of a 10 year industry learning process, low carbon living provides the householder a net economic benefit by around the 8th year of the assumed 40 year life for the building. The additional construction costs and subsequent technology replacement costs are quickly overtaken by a steady stream of economic benefits and positive experiences enjoyed by the householder.

This report notes important limitations to the data, particularly those costs and benefits associated with intrinsic experiences. Further research is necessary to establish greater certainty regarding assigned values where empirical evidence was unavailable, and to understand the experiences of those households investing in higher density low carbon living.

And whilst this value proposition analysis is focussed on the householder experience of net zero energy detached homes, many of the experiences are likely to be similar in townhouses and apartments built to a similar energy performance standard. Further value proposition research is planned to examine a wide range of householder experiences associated with higher density low carbon living.

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