

COSTS AND BENEFITS OF A GREEN VILLAGE: DEMONSTRATING LOCHIEL PARK'S VALUE

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Summary

This paper presents the results of a study of costs and benefits of sustainability initiatives currently being implemented in the Lochiel Park green village development project in South Australia (SA). An alternative assessment methodology to that offered by a conventional cost-benefit analysis was developed that considers costs and benefits with reference to a framework of sustainability indicators, both quantitative and qualitative, with a particular focus on the operational phase of urban development. Principles reflected in the approach include considering costs and benefits across the life-cycle of sustainability initiatives, taking into account multiple stakeholder perspectives on costs and accommodating both monetised and non-monetised indicators of cost and benefit. An important finding of the study is that analysis of costs and benefits informed by these principles offers a valuable approach by which to consider investment in sustainable building. Applying the framework to Lochiel Park, the costs and benefits of various water and energy sustainability initiatives were assessed and compared, with results indicating that Lochiel Park initiatives are making an important contribution to sustainable urban development. A number of lessons can be derived from the study to inform future investment in green development.

1. Introduction

The South Australian Land Management Corporation (LMC) is responsible for delivering Lochiel Park, an ambitious green village development located in Campbelltown near the Adelaide CBD. In 2007, LMC commissioned the Institute for Sustainable Futures (ISF) at the University of Technology, Sydney to undertake a study to assess the likely costs and benefits of sustainability initiatives being implemented at Lochiel Park.

An approach to identifying and communicating costs and benefits of sustainability initiatives was developed. The approach drew on the principles and tools of cost-benefit analysis, tailored to meet study objectives in terms of assessing both environmental and social values of Lochiel Park and adapted to make best use of available data. Principles reflected in the approach include: consideration of costs and benefits over the life-cycle of sustainability initiatives (in this case explicitly focusing on the operational phase due to scope and data limitations); assessment of multiple cost perspectives including those of Lochiel Park residents and wider society; and consideration of both monetised and non-monetised costs and benefits. Sustainability initiatives were assessed with reference to a set of indicators developed by ISF in collaboration with LMC and other stakeholders involved in Lochiel Park design and construction. The indicators approach was complemented by a survey of government and private agencies with an interest in Lochiel Park to gauge perspectives on the costs and benefits to each organisation of being involved in the development of a landmark green village.

This paper outlines the approach and results of the ISF study and situates the study in the context of wider questions about valuing sustainability in the urban development sector. Challenges associated with undertaking analysis of costs and benefits in the green building sector are discussed and the approach to valuing sustainable building taken by ISF/LMC is described. Results of the analysis are presented, including water and energy resource savings, costs associated with selected initiatives and implications for future urban green development.

2. Lochiel Park Green Village

In March 2004, the South Australian Premier Mike Rann announced the development of a 'nation leading' green village at Lochiel Park, a site 8 kilometres north east of the Adelaide CBD. The site comprises fifteen hectares of land and is located adjacent to the River Torrens Linear Park.

Lochiel Park is being developed during a period of rapid change, in both the residential development sector generally and in community perceptions about the urgent need for action on critical sustainability issues such as water and climate change. The South Australian Government has invested significantly in Lochiel Park with the aim of ensuring that dwellings are affordable and price-competitive, while at the same time demonstrating sustainability potential of green building, particularly in the areas of water and energy conservation. Recognising that cutting edge technology in the early stages of development can be expensive relative to existing technology, and that there is significant demonstration value in building sustainability into Lochiel Park, the South Australian Government has provided a substantial subsidy that is to be passed on to householders to offset the costs of sustainability initiatives.

Initiatives for achieving water and energy savings at Lochiel Park are outlined in a comprehensive Urban Design Guideline document that requires, among other things, achievement of a minimum 7.5 star design using the AccuRate House Energy Rating tool (AccuRate is the second generation version of NatHERS), photovoltaic panels, electricity demand-limiting devices and a triple pipe system for delivering potable, rain and recycled water to Lochiel Park households. LMC has set an overall energy saving target of 66% and a potable water saving target of almost 80% compared with current Adelaide housing stock.

To achieve the ambitious water saving targets, LMC is implementing a broad suite of initiatives including reducing household water demand, installing raintanks to supply hot water and reusing stormwater to supply non-potable water for a number of household end uses. The overall approach to water management in Lochiel Park is to use fit for purpose water, supplying water of a sufficient quality for different end uses.

The 66% energy saving target will be achieved through increased thermal performance, energy efficient appliances and photovoltaic (PV) systems (Blaess et al. 2006). Dwelling designs submitted by LMC building contractors are required to meet a set of specifications that are described in the UDG and quantified through star ratings and targets embedded in a sustainability rating tool designed specifically for the Lochiel Park development. The Lochiel Park energy initiatives intend to push boundaries well beyond the minimum standards required in regulation. For example, the mandated 7.5 star AccuRate rating for dwellings, is significantly higher than the current South Australian 5 star rating requirement.

Based on the outcomes of an earlier scoping study undertaken by ISF and discussions with LMC, it was agreed that the analysis of costs and benefits would focus on the operational phase of a prioritised list of water and energy initiatives. Ideally, an assessment of costs and benefits would consider the full life cycle of sustainability initiatives from pre-production through to disposal. In this instance, the operational phase was selected for analysis due to scope and data limitations. It should be noted that impacts associated with manufacturing and disposal, for example embodied energy, were therefore excluded from the analysis.

Initiatives selected were those that would best demonstrate the value of investment in sustainability at Lochiel Park, and for which sufficient data was likely to be available to provide a realistic assessment of cost and benefits. The initiatives included in the study were:

- Household water demand management including the installation of efficient fixtures and appliances
- Raintanks to be installed for each Lochiel Park house and plumbed to supply hot water
- Stormwater reuse system supplying non-potable water for irrigation, toilet flushing and clothes washing
- Whole of house energy demand management measures including dwelling design and appliance efficiency
- 7.5 star AccuRate rating dwelling design compared to 5 star dwelling design (incorporating a common air conditioning appliance efficiency in both the base case and Lochiel Park)
- 7.5 star AccuRate rating dwelling design plus 6 star efficiency rating air conditioning appliances compared to 5 star dwelling design plus 5 star efficiency rating air conditioning
- Residential photovoltaic systems

3. Cost Benefit Analysis and Sustainable Urban Development

Cost-benefit analysis (CBA) is an analytical tool widely used to assist decision-makers to prioritise investment of public resources between different projects, programmes, policies or activities. It is based on the theoretical premise that if benefits are defined as impacts that increase human wellbeing and costs are those impacts that reduce wellbeing, then aggregating costs and benefits to all individuals will determine whether there is an overall gain or loss in wellbeing to society. This “social net benefit” test, used by governments to determine whether an option qualifies for investment of public money, is also predicated on the idea that even if some individuals may be worse off as a result of a project or policy, in theory the winners’ gains could be redistributed

to the losers in a way which benefits all individuals – a principle not without its critics (see e.g. Arrow, 1951; Gowdy, 2004).

The Lochiel Park green village residential development represents a new and exciting avenue for governments to invest in promoting sustainable outcomes. However, the application of cost-benefit analysis (CBA) in the area of public investment in privately-owned and constructed residential building developments is less established than other areas of public investment in services or sustainability outcomes. Particular concerns about the application of the “social net benefit” test implicit in CBA for initiatives such as Lochiel Park reflect the limitations of CBA more generally (Pearce et. al. 2006):

- A dollar does not have the same value to all individuals.
- The distribution of impacts is no less relevant than the aggregate net impact.
- CBA results can be biased by omission of key costs or benefits e.g. environmental and other externalities.
- There are challenges associated with the measurement of costs and benefits, mechanisms for taking into account uncertainty and methods for reflecting individual preferences and values.

4. A Stakeholder Approach to Valuing Lochiel Park

In light of the limitations inherent in applying traditional CBA to sustainable urban development, ISF and LMC developed an alternative approach to measuring the costs and benefits of Lochiel Park sustainability initiatives. The approach was informed by the principles and tools of cost-benefit analysis, adapted to make best use of available data and to enable meaningful communication of the value of the water and energy saving efforts.

One of the principles informing the ISF/LMC approach was the importance of considering the multiple cost perspectives inherent in a development such as Lochiel Park, where private and public agencies as well as residents and wider society have a stake in the investment and its returns.

An initial step in developing an approach to valuing sustainability at Lochiel Park was therefore to undertake a stakeholder analysis, identifying the various cost/benefit perspectives relevant to investment in sustainability. There are two ways in which Lochiel Park stakeholders are affected by housing development – firstly, through market exchanges (goods and services, in exchange for money) and, secondly, non-market impacts (externalities that affect stakeholders, but are not monetised or traded in markets). The stakeholder analysis, shows market exchanges and changes to the traditional distribution of money, goods, services and externalities between the various actors and organisations involved in urban development (Figure 1).

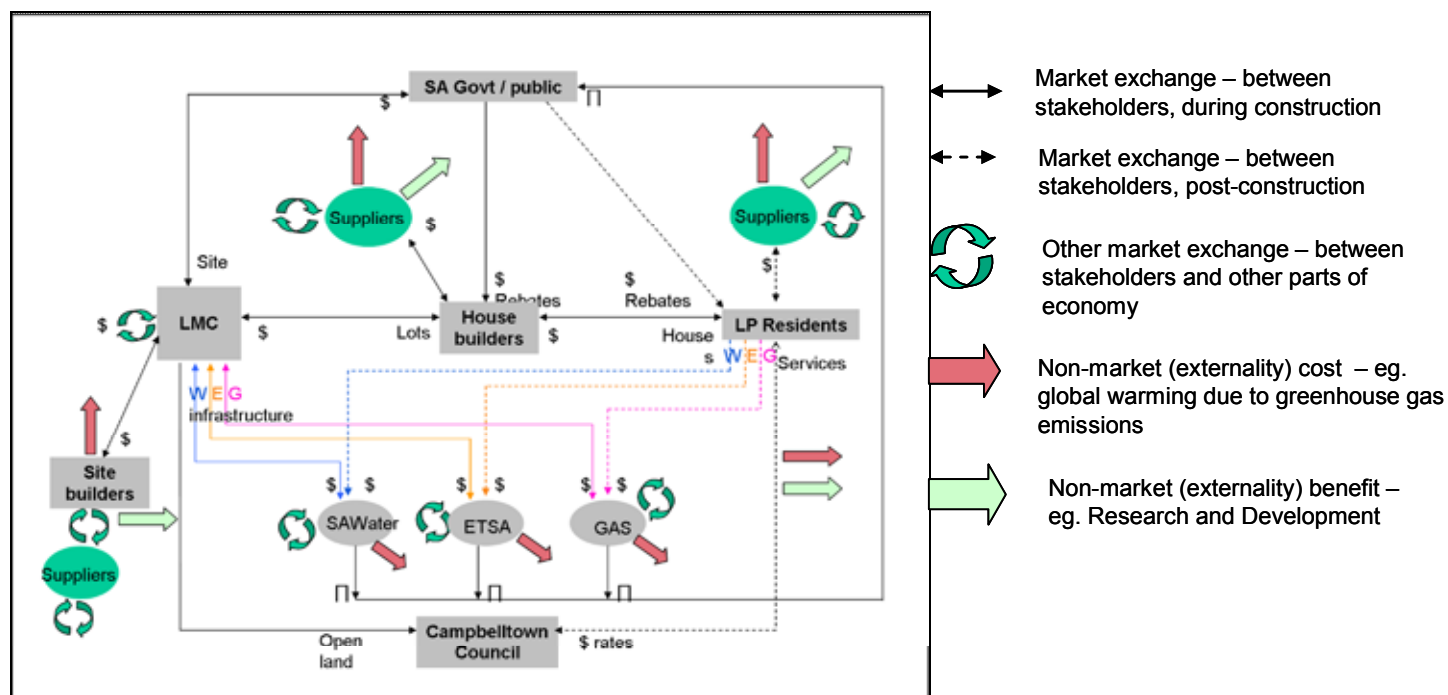


Figure 1 Stakeholder mapping of the distribution of costs and benefits related to Lochiel Park

5. Indicators of Lochiel Park Value

Drawing on the stakeholder mapping exercise, and in discussions with LMC and other organisations involved in the design and/or construction of Lochiel Park, categories for assessment of the benefits of Lochiel Park sustainability initiatives were identified. Categories of indicators selected were those considered to best reflect the range of impacts of sustainability initiatives across the operational life-cycle phase. They were also selected for their capacity to enable consideration of the spectrum of values associated with sustainability initiatives - both monetised and non-monetised. The categories of indicators are:

Resources saved - delivery of services with fewer resources is one of the most effective ways to improve sustainability and a reduction in resource (water and energy) consumption therefore represents a benefit for Lochiel Park residents and for the wider community.

Reduction in household bills - reduced resource consumption results in reduced household spending on water and energy bills and delivers direct financial benefits for Lochiel Park residents.

Greenhouse gas emission reductions - anthropogenic climate change, attributed to increased concentrations of greenhouse gases in the earth's atmosphere arising from human activities, has been identified as one of the greatest challenges faced by humankind. Scientific consensus, as demonstrated through the Intergovernmental Panel on Climate Change, is that there is an urgent need to dramatically reduce greenhouse gas emissions. There is therefore a societal (and global) benefit from initiatives that reduce consumption of fossil fuel-based energy, and thereby greenhouse emissions, in a residential development.

Value for money - an important indicator for assessing the relative costs and benefits associated with sustainability initiatives is value for money or the return on investment in Lochiel Park sustainability initiatives. Value for money is significant for residents (both Lochiel Park and elsewhere) when determining how to invest in sustainable living and also for guiding decision making about public policies, programs and investments for sustainability.

Ecosystem and community services - in addition to quantifiable benefits relating to resource and bill savings, Lochiel Park sustainability initiatives will contribute to the improvement of ecosystem services such as stormwater filtration and increased/improved habitat for birds and other wildlife and also the provision of community amenities such as open public space.

Cultural change towards sustainable living - there are indirect benefits associated with green development in terms of its contribution to a wider societal shift towards sustainability. The cultural and practical considerations associated with sustainable housing and sustainable living are widely promoted through high profile green development initiatives.

These six indicator categories convey the spectrum of ways in which Lochiel Park sustainability initiatives could add value from the perspective of different stakeholders. These were considered with reference to costs, using actual cost data provided by LMC. Where actual cost data was unavailable, best estimates were used based on information from industry sources about costs associated with various fixtures, appliances and design features.

Values relating to resources saved, bill savings, GHG reductions and value for money were assessed with reference to a set of quantitative indicators, as outlined in Table 1. Values associated with ecosystem and community services and cultural change towards sustainable living were assessed qualitatively through a stakeholder survey.

Table 1 Quantitative indicators for measuring the value of sustainability initiatives at Lochiel Park

Resources saved	Resource savings in kL or kWh for an individual Lochiel Park household and for the whole of Lochiel Park (106 households plus water used for park irrigation).
Reduction in household bills	Bill savings as a result of energy or water saved over a 10 year period from the perspective of an individual Lochiel Park household.
Greenhouse gas emission reductions	Avoided greenhouse gas emissions due to Lochiel Park energy initiatives calculated by applying a greenhouse gas conversion factor (in CO ₂ equivalents) to the energy savings and an "avoided social damage cost" value to the avoided greenhouse gas emissions.
Value for money	Net present value of each sustainability initiative reported on a per-household basis based on capital costs and discounted operating costs and bill savings associated with the selected initiatives. Cost per unit of resource saved expressed as \$/kL or \$/kWh saved over a 10 year period.

Modelling exercises, which estimate future energy and water savings and their value necessarily, make a number of assumptions about the future. For example, although site construction had commenced at the time of the study, not all key parameters were yet known with certainty. Modelling also includes assumptions about the choices of future residents, such as technology, and the efficiency of designs, appliances and fittings. Most significantly, all modelling explicitly or implicitly includes assumptions about the behaviour of future residents.

Finding appropriate data, and in particular baseline data against which to compare sustainability costs and benefits was a constant challenge during the study. To resolve data issues and to ensure that the final outcomes of the study were accepted by all participants, a collaborative approach was taken to developing the study parameters and establishing inputs. A two day workshop was held with LMC, Lochiel Park builders and water and energy consultants and ISF worked closely with LMC in all aspects of study design and data collection. This approach meant that LMC was engaged in the process and had a clear understanding of the outputs, outcomes and limitations of the study. The process emphasised the importance of understanding non-financial impacts that are difficult to assess, as well as the monetised costs and benefits of the assessed initiatives. In both respects, the study was different to more traditional cost-benefit or cost-effectiveness analysis.

6. Findings and lessons

The primary conclusion of the study was that LMC and the South Australian government are making an important contribution to change towards sustainable living through investment in the Lochiel Park development. Quantified costs and benefits differed for each of the initiatives considered in the analysis, and some presented a more positive picture than others, as would be expected when dealing with a rapidly evolving field in technological, social and economic terms. The qualitative analysis complemented quantitative indicators of value, suggesting that the long-term impacts of the cultural change potential of the development in the building industry and the wider South Australian community are important. This section outlines some of the findings of the analysis of water and energy saving initiatives and describes results of the stakeholder survey as a means to identify some of the less tangible benefits and costs associated with Lochiel Park.

6.1 Water initiatives

As a result of investment in innovative water infrastructure and improvements in household water use efficiency, Lochiel Park households will use on average 75% less mains potable water than an average Adelaide household. This is an impressive saving, largely due to using recycled stormwater for non-potable needs including clothes washing, toilets and irrigation. Bill savings for residents are also significant, with Lochiel Park residents saving approximately 40% on water bills over 10 years. The most notable bill savings result from household demand management initiatives including the mandating of 4 star WELS rated toilets and 3 star washing machines and showers.

Analysis of bill savings associated with water initiatives in the study was undertaken using a 10 year price path with water prices increasing in real terms by 3% per annum (as advised by SA Water). More recently, with the announcement that a desalination plant will form part of the water supply system for Adelaide, it seems likely that water prices will rise at a much faster rate – a planned price increase of 42% in one year has been reported (Faulkner, 2007). If this increase occurs, bill savings resulting from Lochiel Park water initiatives would almost certainly be higher than those reported in this study.

The cost effectiveness of Lochiel Park water initiatives differs considerably as shown in Figure 2. Household demand management is by far the best value for money, with a cost per kL of water saved of \$0.15 over a 10 year period. Raintanks are relatively expensive at around \$18/kL. The cost of the stormwater reuse system is about \$6/kL including the significant portion of water which will be used for park irrigation and comparable to raintanks at \$19/kL when irrigation water is excluded. The analysis shows that investing in household efficiency is a cheap and effective measure for improving water sustainability, while raintank installation and stormwater recycling are relatively expensive resource saving options. However, the magnitude of total water savings in Lochiel Park would not be possible from efficiency alone. To achieve the percentage reduction in household water use the stormwater reuse system is particularly important. There are also additional benefits resulting from the stormwater system in that the constructed wetlands will provide a stormwater treatment service for two sub-catchments, thereby improving the quality of water discharged into the Torrens. Similarly, it is important to acknowledge that there would be additional costs associated with water initiatives such as energy use, which were beyond the scope of consideration for this study.

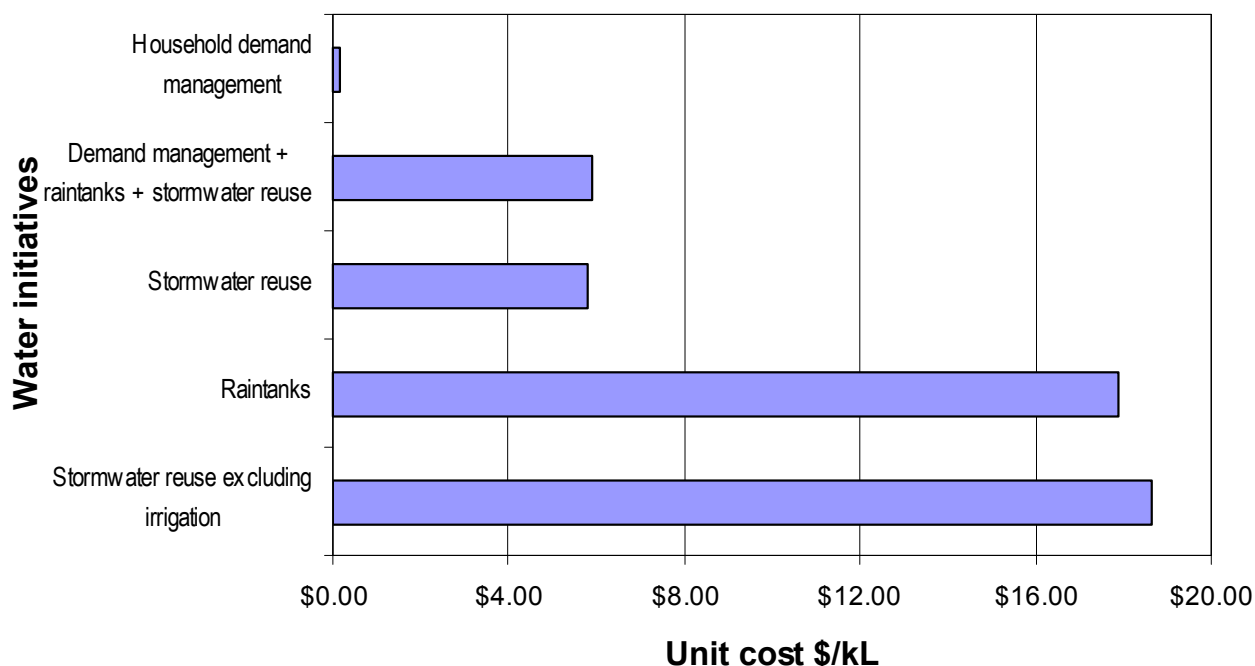


Figure 2 Relative cost effectiveness of Lochiel Park water initiatives

6.2 Energy initiatives

The study indicated that measures implemented to achieve very high energy efficiency in Lochiel Park dwellings are expensive – the marginal net cost to a resident elsewhere of moving from a 5 star to a 7.5 star rating is close to \$18,000 over 10 years. There may be more cost-effective ways to achieve the same dwelling efficiency outcomes, however the ability of builders to achieve the rating cost-effectively is highly impacted by client preferences. For example, client preference for large windows leads to a requirement for expensive shading to achieve the necessary efficiency.

Figure 3 shows the results of comparison of unit cost (present value of upfront costs and operational costs, per kWh saved over 10 years and 25 years for PV systems) of PV systems, additional 2.5 star dwelling design efficiency to achieve 7.5 star, and the same design efficiency plus 6 star air conditioning.

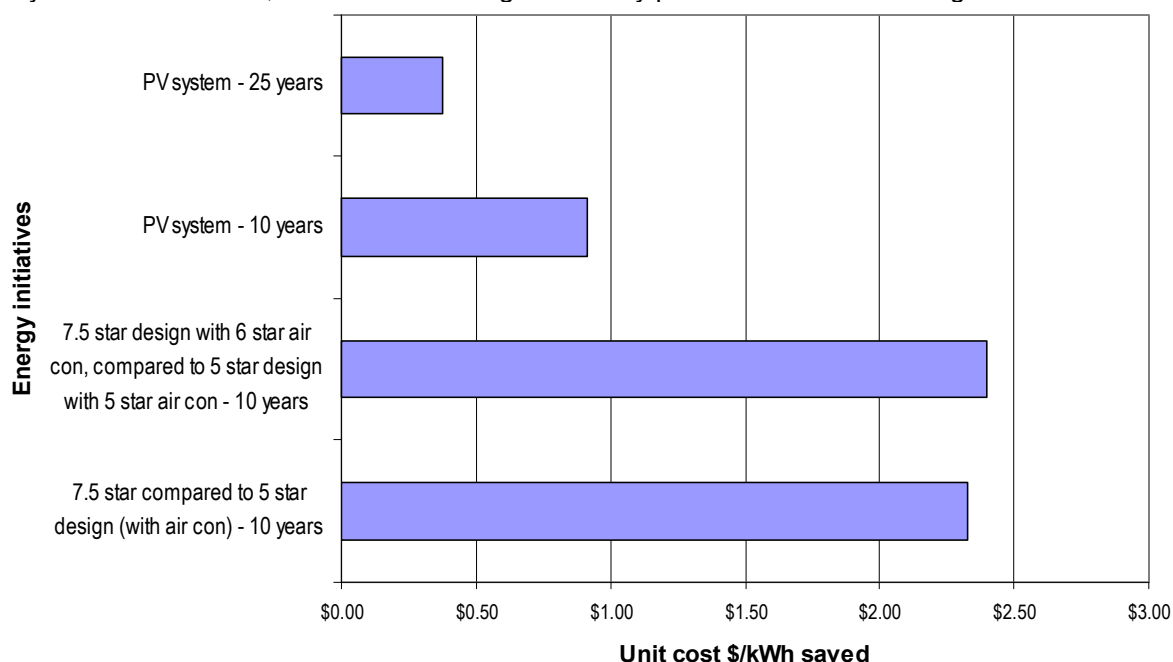


Figure 3 Relative cost effectiveness of Lochiel Park energy initiatives

Overall in this analysis, PV systems appear to be the most cost-effective option with a unit cost of \$0.90 over 10 years, compared to \$2.30 over 10 years for a 2.5 star increase in dwelling design efficiency from 5 to 7.5 star. PV cells are compared in this study to top-end efficiency measures i.e. the difference between 5 and 7.5 star dwelling efficiency. It is highly likely that more basic efficiency measures, for example dwelling orientation, could contribute to a 5 star dwelling with marginal upfront costs close to zero. These basic measures would be highly cost effective compared to PV systems. The substantial rebates available for PV systems also improve their cost effectiveness from a resident perspective compared to high-end dwelling design efficiency in this analysis.

The absolute marginal resource (and financial) savings of the shift from 5 to 7.5 star rating are small compared to the absolute energy supply from PV cells – 8,000 kWh per household over 10 years saved through the additional 2.5 star dwelling design efficiency, compared to 22,000 kWh of electricity supplied by PV cells over 10 years. There may therefore be an ‘efficiency threshold’ beyond which further investment in efficiency is less cost-effective than alternatives to achieve a given level of reduction in fossil fuel-based energy consumption. It should be noted that PV systems currently incorporate significant embodied energy and this should be factored into a full comparative life-cycle analysis of alternative energy supply/demand management options.

A further factor affecting the cost effectiveness of all options is the low retail price of electricity and gas – around 18c per kWh for electricity and 1c per MJ for gas. This means that even where resource savings (for example from PV cells) are higher, the financial benefits to residents in terms of household bill savings are not great. Analysis of the impact of a potential feed-in tariff of 44c per kWh for export of PV electricity generation to the electricity grid shows that increasing the financial return (savings) to residents for electricity export increases the private return on investment to residents. The broader implication of this finding is that increases in retail energy tariffs brought about through, for example carbon pricing, are likely to improve the cost effectiveness of the options considered in this analysis. Carbon pricing effectively begins to factor into tariffs externalities associated with greenhouse gas emissions that are currently and have previously not been taken into account.

The study quantified the likely greenhouse gas emissions reductions and associated avoided social damage costs from Lochiel Park energy initiatives. The predicted greenhouse emissions reductions associated with Lochiel Park energy initiatives, in the order of 40-50% per household from energy demand management measures, demonstrate the potential for substantial absolute reductions if the initiatives were scaled up to larger developments. Social damage costs of carbon are an indicator of externalities that are currently not factored into energy tariffs. Using a social damage cost of carbon from the Stern Review of the Economic Costs of Climate Change (Stern 2006), the study quantified likely damage costs avoided as a result of Lochiel Park energy initiatives. The avoided damage costs from all houses collectively through dwelling design and PV systems could be as much as \$35,000 per annum. This demonstrates that Lochiel Park energy initiatives may result in important societal benefits that go beyond the level of residential bill savings.

6.3 Qualitative analysis – costs and benefits to stakeholders

A stakeholder workshop and survey was used to assess perceptions of costs and benefits associated with involvement in Lochiel Park design/construction with a view to capturing some of the less tangible outcomes of Lochiel Park, for example benefits related to research and development. Results indicated that a perceived value of Lochiel Park was the opportunity to test cutting-edge technologies, in order to provide valuable information that will enhance the future potential for builders at other developments or applications.

Discussions and surveys of builders’ organisations revealed a perception that involvement in Lochiel Park had led to substantial benefits in terms of learning about sustainable new products, technologies and building methodologies, new market opportunities for individual companies, and the opportunity to “lead” the sector as a whole. Builders also identified that they believed that the wider community would benefit by the demonstration of cost-effective sustainability initiatives. However, as supported by the evidence from the quantitative analysis, one respondent noted that the overall demonstration effect of Lochiel Park might be dampened, because the relative incremental cost of building a 7.5 star house over a 6 star house might be disproportionately high compared to the energy savings achieved.

Although surveys of residents and the community was beyond the scope of this study, some stakeholders noted that they expected general benefits for the wider community, in terms of sustainability outcomes of future developments. The visibility of the Lochiel Park development, promotion of the sustainability benefits during the

remainder of construction and beyond to broader South Australian and Australian communities has the potential to encourage wide-ranging behaviour and attitudinal change towards sustainable living.

Some sustainability initiatives excluded from this study are likely to contribute significantly to the sustainability value of Lochiel Park. For example, wetlands, a key feature of the stormwater management system, combined with an urban forest, could add significantly to the amenity value not only for residents of Lochiel Park but also potentially for the local community. There is potential for this benefit of Lochiel Park to the local community to be explored through further qualitative research, for example in exploring links between green space and health.

7. Conclusion

Lochiel Park is being developed to demonstrate significant reductions in energy and water use to become a nation leading green village. It has raised the bar. There are a number of lessons from the Lochiel Park study that can inform investment in future sustainable urban development. An important finding is that analysis of costs and benefits that accounts for multiple cost perspectives and addresses both monetised and non-monetised values offers a valuable method by which to assess investment in sustainable building. It enables comparison of various options for achieving sustainability outcomes and ensures that costs and benefits and their distribution are made explicit.

Analysis of costs and benefits of various sustainability initiatives should ideally be considered during the design phase of development to enable comparison of options and to ensure the most context-appropriate initiatives are selected. This would be best done with reference to a sustainable building framework that identifies principles and desired outcomes for green building on a case by case basis, to facilitate transparent decision making informed by consideration of the multiple relevant perspectives on costs and benefits.

The ISF/LMC approach to assessing costs and benefits of Lochiel Park represents an alternative means for determining the value of green development based on sustainability indicators, comparative assessment of initiatives and stakeholder analysis. The approach builds on conventional cost-benefit methodologies by enabling consideration of different stakeholder perspectives and incorporation of some of the less tangible benefits and costs associated with sustainable urban development.

In the case of Lochiel Park green village, the assessment of costs and benefits associated with water and energy saving initiatives indicated that LMC and the South Australian government are making an important contribution to urban sustainability. Quantified costs and benefits differ for each initiative considered in the analysis, and as expected some present a more positive picture than others, however it is clear that LMC is achieving substantial resource savings for the South Australian community by investing in water and energy saving initiatives. With expected increase in water and energy prices in the shadow of carbon emission trading scheme the benefits of the initiatives are likely to increase in value for residents and society as a whole. The less tangible values of Lochiel Park – including its provision of ecosystem services and contribution to mainstreaming sustainability in the urban development sector – are difficult to capture comprehensively, but the study suggested that there are long-term benefits associated with cultural change in the building industry and the wider community that will be realised when the development is completed and the community has developed.

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A SERIES OF DESIGN METHOD AND MEASUREMENT RESULTS OF OFFICE BUILDINGS UTILIZING NATURAL VENTILATION IN CENTRAL TOKYO

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Abstract

In recent 10 years in Tokyo Japan, the idea of HVAC design for office in Tokyo has drastically changed: from the previous idea of actively air-conditioning super-insulated space, to energy saving air-conditioning using natural ventilation during relatively cool seasons. Detailed planning such as site location, expected wind characteristics around the building, shape of the building and its air inlets/outlets positions, are needed for designing I ventilation for every single building.

This paper reports four office buildings introducing natural ventilation with their design method and observation results of indoor environment and energy consumption. The design methods vary wide in range: under floor air-conditioning in combination with natural ventilation, hybrid air-conditioning system using natural ventilation and air-conditioning machine simultaneously, and natural ventilation applied to super high-rise building.

From the results we have obtained, there was considerable variation of air change rate from 1 to 6 times/hour depending on difference in size of opening for ventilation or effectiveness of ventilator. In addition, it was determined that by using hybrid air conditioning system using natural ventilation and air-conditioning machine simultaneously, for air-conditioning load that were not eliminated only by natural ventilation, to effectively lengthen natural ventilation operation of air-conditioner. As for natural ventilation for super high-rise building, utilizing wind around the building will take in enough air volume by natural ventilation into the building.

1. Outdoor Condition of Tokyo and Possibility of Natural Ventilation

Considering heating in winter, and cooling in other seasons for HVAC system in an office building in Tokyo was common until late 1980. However, due to improvement of thermal insulation and increment of internal heat inside the building, cooling throughout the year became general after 1990. These transition of design condition caused building with super-insulation and fixed window to change into building with openings for ventilation, natural ventilation and night purge in early 1990.

Outside air temperature through the year in Tokyo is shown as figure 1, absolute humidity condition through the year in Tokyo is shown as figure 2. Natural ventilation is effective during seasons except between July to end of September which outside air temperature is higher than 25• •and absolute humidity is higher than dew point of 19• •DB. Since air-conditioning in the office has changed to cooling for most of the year in recent years, natural ventilation is also effective even during winter seasons to maintain inside thermal environment sound by using outside air.

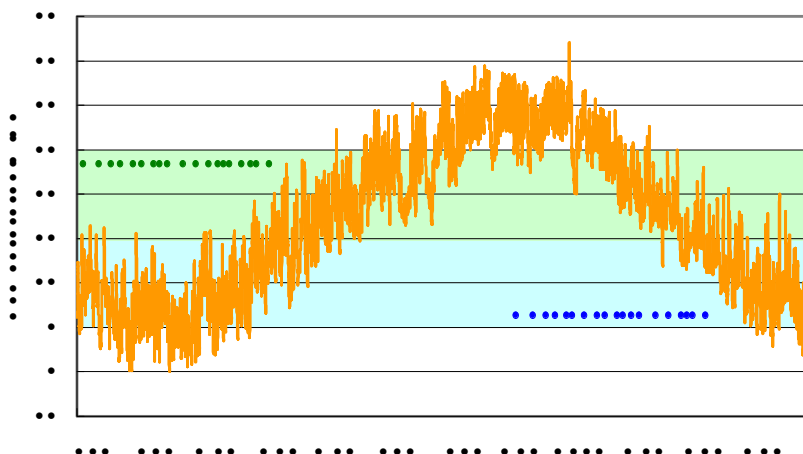


Figure 1 Outside air Temperature, Tokyo 2000.