Sustainability Planning Scheme Amendment – Cost-Benefit Analysis

A report for the Municipal Association of Victoria on behalf of CASBE | 28 March 2022

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1 Introduction

1.1 About this report

The *Council Alliance for a Sustainable Built Environment* (CASBE) is an alliance of Victorian councils committed to the creation of a sustainable built environment within and beyond their municipalities. CASBE's focus is on seeking better sustainability outcomes in the built environment using the planning permit application process. CASBE is auspiced by the Municipal Association of Victoria (MAV). MAV is the peak body for local government in Victoria.

MAV, on behalf of CASBE, has sought expert advice to enable the development of a planning scheme amendment, with a range of new elevated standards of sustainability in buildings.

The purpose of the elevated standards is to ensure that new buildings and significant alterations and additions are planned and designed in a manner which mitigates and adapts to climate change, protects the natural environment, reduces resource consumption and supports the health and wellbeing of future occupants.

This report presents the results of the cost-benefit analysis of the proposed elevated standards. As outlined further in this report, it builds on other workstreams in the project including planning advice and technical and development feasibility. Further information on the standards is provided in the reports for these workstreams.

1.2 The case for change

There are numerous benefits and performance improvements that arise from more sustainable buildings. These include operational cost savings from improved energy and water efficiency, and higher-quality building outputs. Improved indoor environment quality has been shown to improve health outcomes and employee productivity.[1] More sustainable buildings can also help to manage climate, regulatory, or other environmental risks.

Despite these potential benefits, there are several market failures that inhibit new developments from achieving more sustainable outcomes. These include:

- **Information asymmetry** – a lack of information by purchasers or renters on the sustainability performance of buildings. In particular, building qualities like efficiency and indoor environment quality are difficult to detect and verify prior to purchase or lease. When buyers and sellers do not have perfect information, it can lead to inefficient outcomes

[1] For example the following articles discuss various productivity and health benefits from improved indoor environment quality, https://theconversation.com/research-shows-if-you-improve-the-air-quality-at-work-you-improve-productivity-76695; https://v2.wellcertified.com/health-safety/en/air%20and%20water%20quality%20management; https://www.researchgate.net/publication/273746860_Costs_and_benefits_of_IEQ_improvements_in_LEED_office_buildings

- **Negative externalities** - negative externalities may mean that suboptimal decisions are made in the absence of intervention. For example for energy consumption, energy prices that do not fully reflect the economic cost of consuming energy (including the cost of greenhouse gas emissions) can lead to overconsumption of energy. There are similar issues related to the embedded carbon in construction materials.

  Negative externalities mean that energy consumption is higher than economically efficient levels and there is under-investment in energy efficiency.

- **Principal-agent problems** - where builders or designers do not share the objectives of those purchasing new homes (for example to minimise energy bills)

These problems and market failures suggest a form of policy response or intervention may be needed.

2 Methodology

2.1 Overview of Cost-Benefit Analysis

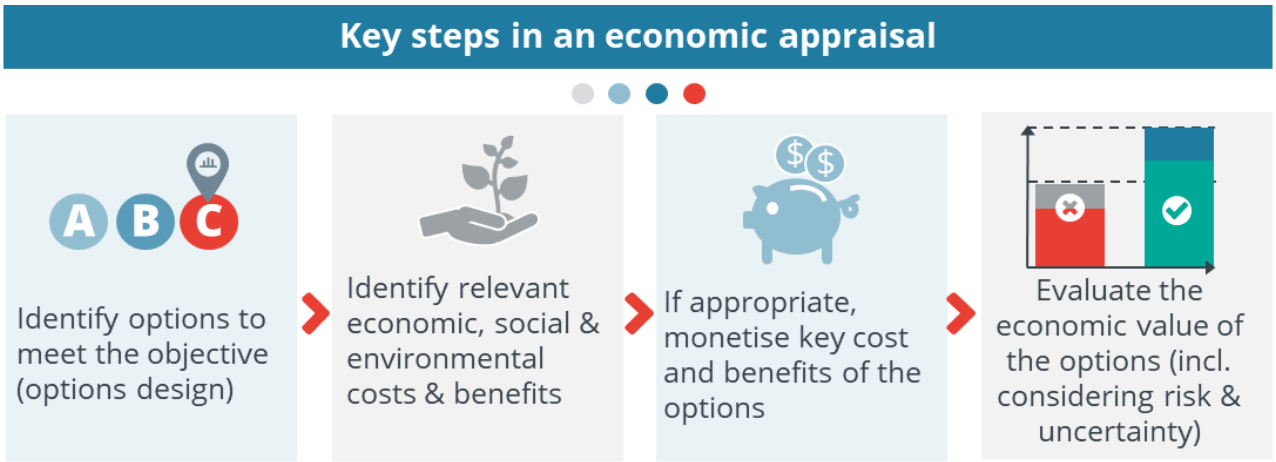
A cost-benefit analysis (CBA) provides a robust framework to assess the impacts of an intervention. A CBA is an assessment tool that compares the costs associated with a potential intervention with the benefits. The analysis is incremental in that it looks at additional costs and benefits over and above a "business as usual" scenario (the base case). The process is shown in

Figure 1 below and involves:

- **Step #1:** Identifying the appropriate Base Case and alternative interventions options (for comparison against the base case)
- **Step #2:** Identifying the range of relevant, incremental economic, social, and environmental costs and benefits of the options
- **Step #3:** Quantifying and monetising (where appropriate) a subset of the incremental economic, social and environmental costs and benefits

Step #4: Undertaking a CBA of the incremental economic value of the options (including considering risk and uncertainty using sensitivity analysis)

Figure 1: CBA process



Source: Frontier Economics.

While a CBA is an economic analysis, it looks to value economic, environmental and social impacts. The focus of a CBA is on 'real resource' changes from the point of view of society. That is to say, the focus is on incremental changes in scarce resources (labour, material, natural capital etc.) from the point of view of Victorian society. Financial transactions (such as the purchase of land or the payment of a levy) which make one party better off and another worse off are "transfers" which are excluded from a CBA as they result in no change for society.

Importantly for this analysis, property value uplift is not a real resource impact. Rather this is a financial benefit for a property owner. However, a number of the factors driving the higher property value – lower ongoing utility costs and improved amenity benefits etc. are captured in this analysis.

2.2 How this CBA fits with other workstreams and typologies assessed

This CBA builds on the planning and environmentally sustainable development (ESD) components of the elevating ESD targets project. As outlined in **Figure 2**, the planning advice refined the Sustainability Planning Scheme Amendment standards, the technical ESD component then estimated the costs and impacts associated with the design response for the standards and then this CBA values and profiles impacts based on available data and evidence.

Figure 2: Overarching project process

Source: Frontier Economics

In line with the case study typologies developed in the project, this CBA analyses eight building typologies across a range of locations (ie. inner urban, suburban and regional). For each typology the analysis compares the costs and benefits of an option or *intervention case* (with the Sustainability Planning Scheme Amendment) against two base cases (one for councils with an existing ESD Policy and another for councils that do not have an existing ESD Policy).[2] These typologies and base cases are outlined in **Table 1** and are hereafter referred to as scenarios. These scenarios align with those analysed across the project as a whole.

[2] The exception here is the RES 5 typology which only has a single base case (a council with no existing ESD policy).

Table 1: Typologies and base cases included in the analysis.

Typology	Inner Urban	Suburban	Regional
(RES1) Large residential mixed-use development >50 apartments and small retail	ESD Policy	Non-ESD Policy	
(NON-RES 1) Large non-residential >2,000 m2 GFA office development	ESD Policy	Non-ESD Policy	
(NON-RES 2) Large industrial >2,000 m2		ESD Policy	Non-ESD Policy
(RES 2) Small multi-dwelling residential <3 dwellings		ESD Policy	Non-ESD Policy
(RES 3) Small multi-dwelling residential >5 dwellings but < 10 dwellings	ESD Policy	Non-ESD Policy	
(RES 4) Small residential apartment building >10 dwellings but <50 dwellings		ESD Policy Non-ESD Policy	
(NON-RES 3) Small non-residential office and retail <2,000 m2	ESD Policy		Non-ESD Policy
(RES 5) Single dwelling and/or residential extensions greater than 50 m2		Non-ESD Policy	

Source: Frontier Economics

2.3 Impacts

The next step in the CBA process (following the identification of a range of potential options) is to identify the range of incremental economic, social and environmental costs and benefits that accrue to the local and broader Victorian communities, compared to the Base case.

The proposed Sustainability Planning Scheme Amendment (the application of which is the difference between our options and the Base Case) covers a broad range of changes to building requirements across the broad themes of:

- Operational Energy
- Sustainable Transport
- Integrated Water Management
- Indoor Environment Quality
- Circular Economy
- Green Infrastructure

Note that the themes above were based on an early categorisation which removed 'Climate Resilience' and redistributed standards under that theme. This theme has now been reintroduced. In this report, results have not been reported separately for climate resilience however to avoid any doubt, the costs and benefits related to climate resilience are still included as part of other themes. In addition, the 'Circular Economy' category was split into two called 'Waste and Resource Recovery and 'Embodied Emissions'. More information is contained in the Technical ESD report.

Figure 3: Overview of key cost and benefit themes considered in this analysis

Source: Frontier Economics

The breadth of these themes leads to a broad range of potential impacts. To ensure that this CBA takes a robust approach to analysing these broad impacts, a three-stage approach was taken:

1. Logic mapping exercise undertaken to identify ultimate impacts that should be assessed by category (as opposed to an intermediate implication). The logic mapping process drew on our expertise across these key themes and a range of Australian literature (See Appendix C for more detail). The logic maps started from the theme objective, identified implications and then key impacts.
2. Longlist of potential impacts developed by drawing on the logic mapping exercise.
3. Further research undertaken to identify which outcomes can be quantified and those which should be considered qualitatively (See Appendix C for more detail).

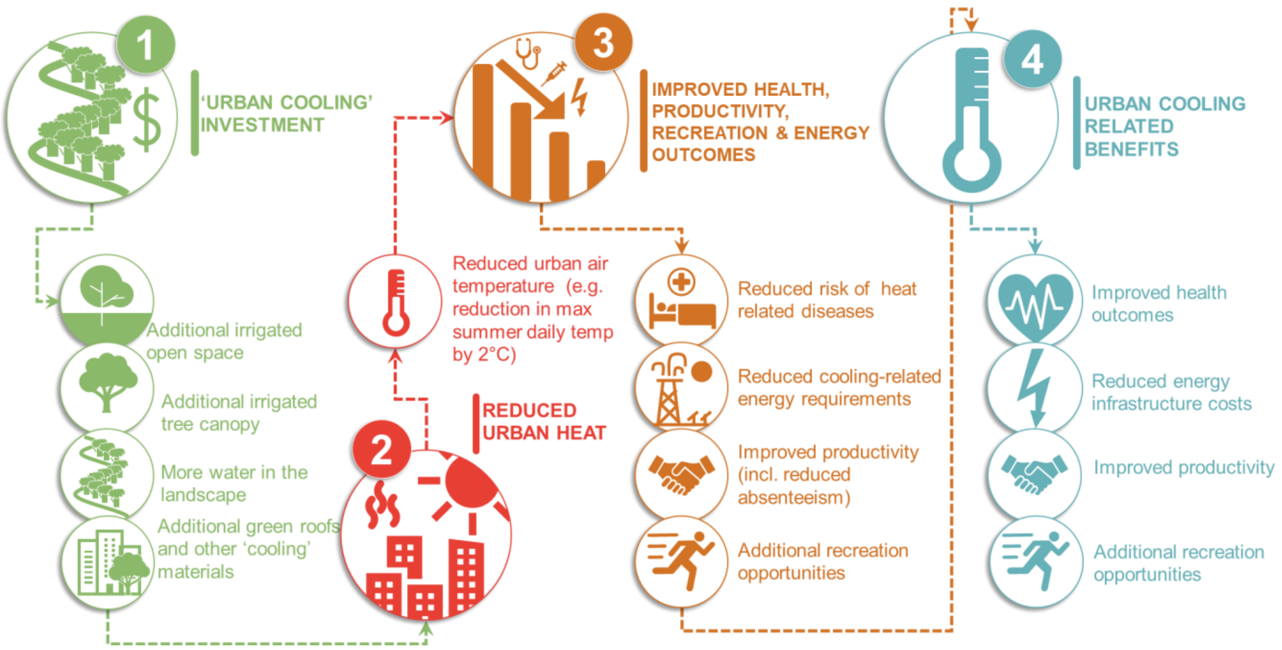
Our logic mapping and potential impacts is shown below in **Table 2**. Importantly, it is the end outcome that are being identified and, if appropriate, valued in the CBA (where possible) as opposed to the initial step in the causal chain or the overall objective.

In the discussion below, we elaborate on a logic mapping approach for urban heat. As shown in **Figure 4**, investment to manage urban heat (including investment in irrigated open space and tree canopy, water in the landscape and other cooling-materials such as green roofs) can reduce the urban air temperature (e.g. reducing the max summer daily temperature), providing economic, environmental and social (or liveability-related) benefits to the community.[3] This includes:

[3] See for example Sydney Water Corporation (2017), Cooling Western Sydney A strategic study on the role of water in mitigating urban heat in Western Sydney; CRCWSC (2016), Impacts of Water Sensitive Urban Design Solutions on Human Thermal Comfort. Available at: https://watersensitivecities.org.au/wp-content/uploads/2016/07/TMR_B3-1_WSUD_thermal_comfort_no2.pdf; Kabisch, N., et al. (2017). "The health benefits of nature-based solutions to urbanization challenges for children and the elderly–A systematic review." Environmental Research 159: 362-373.

- **Reductions in the risk of heat-related diseases** –While urban heat is rarely listed as the cause of death, various studies have found that increased heat levels lead to increased risk of death or disease, especially amongst the most vulnerable in the community: the very young and elderly.[4] A reduction in urban heat can reduce the risk of heat-related diseases, reducing the number of heat-related deaths and the use of health services (reducing the total cost of treatment).
- **Reductions in cooling-related energy requirements –** reduced cooling demand as a result of reduced urban heat, can reduce the generation and network energy infrastructure requirements required to meet future demand. This in turn, defers the operation and augmentation of energy generation and network infrastructure, reducing the future cost of providing the energy infrastructure.
- **Improvement in productivity**– reduced urban heat can lead to improvements in productivity, including reduced absenteeism, which may result from reduced heat stress on the community (for example, reductions in the incidence of disturbed sleep or cancelled workdays due to excess heat).
- **Additional recreation opportunities in the summer** – reduced urban heat can lead to increased participation in active and passive recreation in the summer (in addition to the increased recreation opportunities arising from increased availability of open space).

Figure 4: Link between green infrastructure and urban cooling-related benefits



Source: Frontier Economics

The impacts in the table below are in addition to the incremental upfront and ongoing costs to meet the revised standard (i.e. less any costs under the base case). Note that the impacts that are in **bold** text are those that we have been able to quantify and ultimately, monetise, as discussed in the following section.

[4] See for example, Center for Disease Control and Prevention (2006), Heat Island Impacts. Available at: https://www.epa.gov/heat-islands/heat-island-impacts#3>(viewed January 2018).

Table 2: Logic mapping

Theme	Objectives	Implication	Potential impacts
Operational energy	Net zero operational carbon	• No natural gas or onsite fossil fuel consumption • Maximise onsite renewable energy generation • All residual energy to be 100% renewable purchased through Green Power or similar	• **Reduce GHG emissions arising from reduced grid-based energy demand** • **Reduced energy use, avoiding energy fuel costs and deferring the need for energy network investment**
Sustainable transport	Reduce private vehicle trips, support a smooth transition for the future uptake of electric vehicles (EV)	• Provide for bicycle parking (increase likelihood of residents and workers riding bikes) • Provide EV charger outlets • Shared space EV charging	• Increased active transport and resulting reduction in inactivity-related health benefits / avoided costs arising from increased use of bicycles • Increased uptake of EVs leading to reduced GHG emissions and increased electricity use
Integrated water management	Reduce potable water consumption and improve the quality of stormwater discharging from site	• Provide efficient fitting, fixtures and appliances • Provide for rainwater harvesting (rainwater tanks)	• **Reduced potable water use deferring water network investment** • Reduced stormwater discharge leading to reduced impact of nitrogen and suspended solids. This can lead to improvements in the health of waterways and surrounding ecology. • **Value of recovered organic waste (less cost of recovery)**

Theme	Objectives	Implication	Potential impacts
Indoor Environment Quality	Improve the comfort of building occupants including internal temperatures, air quality and daylight access	• Improved external shading • Improved ventilation • Improved daylight	• Improved productivity • Health benefits from improved air quality inside buildings • Staff health & retention in non-residential buildings • Health benefits from increased natural light
Circular Economy	Improve rates of resource recovery, encourage the use of materials with recycled content as an alternative to virgin material	• Provide a Construction and Demolition Waste Management Plan that sets a landfill diversion target • Utilise low maintenance, durable, reusable, repairable and recyclable building materials	• **Avoided operational costs of landfill and avoided landfill externalities (disamenity)** • **Value of recycled materials less costs of transport/processing**
Green infrastructure	Increase the amount of green infrastructure (such as tree canopy, green roofs and open space) to provide a range of ecosystem service benefits, reduce the contribution of the built environment to the urban heat island effect	• All new developments to meet target Green Factor score • Improved green cover (leading to reduced urban heat island effect)	• Reductions in the urban heat-related diseases • Improved productivity • Reductions in cooling-related energy requirements • Improved biodiversity outcomes • Additional recreation opportunities in the summer

Source: Frontier Economics

2.4 Approach to valuing costs and benefits

The aim in economic evaluation is to value very different measures of impact in consistent monetary terms to enable a comparison of a range of economic, environmental and social (or liveability-related) outcomes.

As discussed above, this analysis has sought to, where possible, monetise key costs and benefits where there is an incremental difference in 'real resource' outcomes between the base case and the intervention case.

Many of these impacts can be considered market impacts as the prices of goods or services are observable in markets. Other impacts, such as the environmental or social impacts (or avoided impacts) can be considered non-market impacts.[5]. Where the incremental costs and benefits have been monetised, these are shown in bold in **Table 2**.

In some circumstances, there was not sufficient data to establish a quantitative causal link or attach a defensible monetary value to the incremental difference between outcomes of the interventions (such as the benefits of IEQ and GI). Where the incremental costs and benefits have been unable to be monetised to include in the CBA in a quantitative way, these are shown un-bolded in **Table 2** and have been qualitatively assessed in **Table 4**.

Consistent with best practice and the Victorian Department of Treasury and Finance Guidelines our analysis has:

- **Drawn upon the best available information**, including information provided by Hip V. Hype on incremental costs and impacts of interventions
- **Focused on impacts in the state of Victoria,** consistent with Victorian Treasury Guidelines. This has involved:
  - including impacts that accrue to people in the local and broader Victorian community
  - excluding impacts that accrue to the Australian (such as wider economic impacts) and international communities.
- **Used accepted and relevant methodologies for monetising key costs and benefits**, including the use of benefit transfer techniques (where appropriate) which draw upon existing literature reflecting the willingness to pay or preferences of a similar community for a similar change in outcome. Recognising the potential limitations of benefit transfer, the approach taken in the CBA adopts – as much as is practicable – a range of studies (mainly in VIC) (see Box 1).

5 As a price cannot be observed and other methods must be used to derive a monetary value.

Box 1: Overview of valuation approaches

There is a range of techniques available to monetise non-monetary economic, social and environmental outcomes. These include primary monetisation approaches (such as market-based and survey-based techniques) and secondary approaches, such as benefit transfer:

- **Primary approaches:** use original data from the project site or context to derive a monetary value for some quantified change in outcomes caused by a green infrastructure intervention. There are two broad categories of primary approaches:
  - **Market-based or surrogate market-based techniques –** uses market prices or people's behaviour in a similar or related market to infer the value of outcomes.
  - **Survey Based -** uses surveys that ask people their willingness to pay to value outcomes.
- **Secondary approaches, such as benefit-transfer,** takes values from a pre-existing study, project, or piece of research (i.e. the 'study site') and applies it to a new project, or context (i.e. the 'policy site'). Judgement is required to determine whether results from a previous study are appropriate to use. In addition to scrutinising the quality of the original study needs to ensure there are no technical weaknesses or biases, important preconditions for benefit transfer include:
  - the impact being valued must be essentially the same (e.g. improved thermal comfort)
  - the base case and extent of change should be similar
  - the affected populations should be similar

Given primary research was outside the scope of this analysis (and can be costly and time consuming), we have primarily considered benefit transfer.

Source: Frontier Economics

The following sections provide further detail on our approach to valuing key costs and benefits.

2.4.1 Data for costs and impacts

The CBA takes cost and impact data from the technical ESD analysis undertaken by Hip V. Hype. This data includes:

- upfront incremental capital costs to meet revised standards
- operational energy and water savings incremental to the base case
- avoided waste to landfill
- reduced embodied carbon
- estimated useful life of assets.

Further information on these costs and impacts is provided in the Hip V. Hype report.

2.4.2 Benefit data

Quantified benefits

To value benefits, we have drawn on robust valuation benchmarks as outlined in **Table 3**, with further information provided at Appendix B.

Table 3: CBA valuation benchmarks

Benefit category	Valuation approach
Greenhouse gas (GHG) emission reduction	Our valuation includes the following steps: • applying the estimated reduction in gas and electricity consumption (obtained from ESD technical workstream) • forecasting emission intensity factors for Victoria during the evaluation period (see Appendix B) • converting reduced gas and electricity consumption into reduced GHG emissions using forecast emission intensity factors • multiplying the reduced emissions by a social cost of carbon ($75/tonne CO2-e) – Frontier Economics estimate of the economic costs, or damages, of emitting one additional tonne of GHG into the atmosphere.
Reduced energy use (electricity & gas)	We have estimated the resource cost savings associated with reduced electricity and gas consumption, including reduced network and wholesale costs: • For electricity network costs, we have based our estimates on published values for the long-run marginal cost (LRMC) from Victorian electricity network distribution businesses ($0.01/kWh). • For deferred gas network costs, we have adopted an estimate of $4.50/GJ based on a recent Consultation RIS undertaken by ACIL Allen • For electricity wholesale costs, we have assumed a flat $70/MWh (Frontier Economics estimate/assumption) • For gas wholesale costs, we have used price forecasts from the Australian Energy Market Operator's 2022 Integrated System Plan (based on new entrant combined cycle gas turbine generator prices) (see Appendix B) See Appendix B for further discussion on why we have not applied a retail bill (representing financial savings) in our approach.

Benefit category	Valuation approach
Avoided health costs of electricity generation	Electricity generation produces air pollution containing particulate matter, nitrogen oxides, sulphur dioxide, as well as other emissions. These can cause health problems such as respiratory illness and can also affect local economies. We estimated the health benefits of avoided coal and gas-fired electricity at $1.78/MWh. See Appendix B for information.
Reduced potable water use	Our valuation approach involves: • applying the estimated reduction in potable water use (in megalitres) (obtained from ESD technical workstream) • multiplying the reduction in potable water use by the estimated LRMC of water supply based on the value advised by Melbourne Water ($2,450/ML).
Reduced embodied carbon	Estimates of reduced embodied carbon obtained from the ESD technical workstream were multiplied by the social cost of carbon discussed above.
Reduced waste to landfill/value of recovered materials	Estimates of reduced construction and demolition waste to landfill (tonnes) were multiplied by the full economic cost of landfill and the net value of recovered materials. This approach provides an estimate of the avoided cost of landfill and value of recovered materials of $125/tonne. See Appendix B for information.
Recovery of organic waste	Estimates of organic waste recovered, obtained from the ESD technical workstream, were multiplied by an average value added for organic waste. To estimate the average value added for organic waste we used data from Australian Organics Recycling Association's publication 'Australian Organics Recycling Industry Capacity Assessment: 2020-21'. This approach provides an estimate of the value added by additional organic waste recovered of $93/tonne.
Residual value	Some assets have a useful life that is greater than the analysis period of the CBA. The residual value is the estimated value of assets at the end of the appraisal period, representing the expected value in continuing use. We calculate residual value as the present value of future benefits.

Source: Frontier Economics

We note that our approach is consistent with advice provided by HoustonKemp to the Australian Government for cost-benefit analysis for residential building energy efficiency (**Box 2**).

Box 2: Guidelines for residential building regulatory impact assessment

HoustonKemp were engaged by the Department of the Environment and Energy to develop a robust methodology for evaluating the benefits and costs of possible future increases in the stringency of the energy efficiency provisions in the National Construction Code (NCC).

Our valuation approach outlined in **Table 3** is in line with HoustonKemp's recommendations, including that:

- benefits of reduced energy use be estimated based on LRMC estimates and wholesale market prices where available
- benefits of reduced GHG emissions be based on forecast emission intensity factors and GHG abatement costs
- health, safety and amenity benefits be dealt with qualitatively (unless they can be readily quantified)

Our analysis is also consistent with HoustonKemp's base case description, and recommended evaluation timeframe of at least 20 years (outlined below).

Source: Houston Kemp, Residential Buildings Regulatory Impact Statement Methodology – Report to the Department of Environment and Energy, 6 April 2017.

Non-monetised benefits

Critically, CBA does not require monetisation of all key costs and benefits. While we have aimed to value as many benefits as possible, some impacts are inherently difficult to quantify and value. This is particularly the case where impacts are not traded in markets, such as 'improved biodiversity outcomes', 'improved thermal comfort', or 'improved aesthetics'.

For impacts which do not have a robust valuation method, or do not have a clearly attributable incremental impact, they have been assessed qualitatively (**Table 4**). Qualitative assessment of impacts aligns with CBA guidance including the Victorian Department of Treasury and Finance.

To provide an indication of whether these benefits would alter the broad narrative of our results, we have included an assessment of materiality. In our discussion of the CBA results, we provide a break-even analysis to show how much unquantified benefits would need to be for scenarios to be equal to the incremental costs.

Table 4: Qualitative assessment

Incremental impacts	Most relevant theme	Materiality	Qualitative assessment (why we have not valued these impacts)
Ongoing cost to meet revised standards	All	Uncertain	Any change in ongoing cost will be dependent on the specific materials and products used in the Sustainability Planning Scheme Amendment option compared to the ESD policy or non-ESD policy base case. The technical ESD assessment haven't proposed specific materials in the design responses (except for recycled content concrete in the Circular Economy theme), which makes any assessment uncertain. At a high level, it is expected that some design responses would increase ongoing costs while others reduce ongoing costs and that the overall impact may not be material.
Health and wellbeing benefits from improved thermal comfort	Operational energy	Minor benefit	Increased thermal comfort can lead to a range of health and wellbeing benefits.[6] The impacts of increased thermal comfort would be expected to be highly context specific – both in terms of the location of the building and how the building is used (i.e. for residential typologies are residents working from home or out of the house 12 hours a day?). For scenarios where the base case has an existing ESD policy there is likely to be a small incremental impact as the base case provides a good level of thermal comfort. The incremental impact may be more for scenarios where the base case does not have an existing ESD policy.
Increased active transport / avoided costs through improved transport mode usage	Sustainable transport	Benefit with unclear materiality	CBA focuses on impacts which are attributable to the intervention. While improved bike access and storage would make active transport more appealing to building users, there are myriad factors which impact on mode choice decisions. As such, while the incremental impact is a benefit it is not possible to isolate the magnitude of this impact.
Increased uptake of EVs leading to reduced GHG	Sustainable transport	Minor impact	Similar to active transport, uptake of EVs is a complex decision with myriad factors including price of EVs, price of operating internal combustion engine vehicles and the

6 For example - Ormandy, D. and Ezratty, V., *Thermal Discomfort and Health: Protecting the Susceptible from Excess Cold and Excess Heat in Housing,* 2015, https://warwick.ac.uk/fac/sci/med/research/hscience/sssh/publications/publications14/thermal.pdf

emissions and increased electricity use			range of EVs. As such, while the incremental impact of reducing vehicle-related emissions is a benefit it is not possible to isolate the exact magnitude of this impact.
Reduced volume of stormwater leading to reduced nitrogen and suspended solids	Integrated Water Management	No impact	The technical ESD assessment identifies that both ESD and non-ESD policy base cases include rainwater tanks for stormwater collection and meet the requirements for the quality of stormwater discharged from the site. Given this, it appears there is unlikely to be any incremental impact related to stormwater.
Health benefits from improved air quality inside buildings	Indoor Environment Quality	Benefit with unclear materiality	Increased natural ventilation should lead improved air quality which, in turn, leads to improved health outcomes.[7] The impacts would be highly context specific – both in terms of the location of the building and how the building is used. The incremental impact depends on the base case. For example, for RES 1 the ESD Policy base case includes 100% of apartments being naturally ventilated whereas the non-ESD Policy base case includes "some natural ventilation." In this example, there may not be an incremental impact on air quality when compared to the ESD Policy base case but there may be some incremental impact when compared to a non-ESD policy base case.
Staff health & retention for non-residential	Indoor Environment Quality	Benefit with unclear materiality	There is some evidence that improved indoor environment quality leads to improved staff health (fewer sick days) and improved staff retention.[8] The magnitude of the impact will be highly context dependent, particularly with respect to the base case. For example, in Non-RES 3 the ESD Policy base case includes natural ventilation and daylight requirements have been too location specific to be assessed by the technical ESD assessment.

7 For example - Al horr, Y., Arif, M., Kaushik, AK., Mazroei, A., Katafygiotou, M. and Elsarrag, E., *Occupant productivity and office indoor environment quality : a review of the literature*, 2016, https://usir.salford.ac.uk/id/eprint/39106/3/BAE-D-16-00533_final%20manuscript[1].pdf and Fisk, W., Health and productivity gains from better indoor environment and their relationship with building energy efficiency, 2000, https://www.annualreviews.org/doi/full/10.1146/annurev.energy.25.1.537

8 For example, REHVA, *Indoor Climate and Productivity in Offices: How to integrate productivity in life-cycle cost analysis of building services*, 2017, https://biblioteka.ktu.edu/wp-content/uploads/sites/38/2017/06/06_Productivity_2ed_protected.pdf. The International WELL Building Institute cite the following source for healthy buildings lowering staff turnover and burnout - Leiter M, Maslach C. Areas of Worklife Survey. Mindgarden. https://www.mindgarden.com/274-areas-of-worklife-survey.

Health benefits from increased natural light	Indoor Environment Quality	Benefit with unclear materiality	There is some evidence that improved natural light in buildings cause health benefits.[9] However, the daylight requirements have been too location specific to be assessed by the technical ESD assessment. As such the incremental impact is unclear.
Reduced risk of heat-related diseases	Green Infrastructure	Benefit with unclear materiality	A benefit of urban greening is reduced urban heat island which can reduce the risk of heat-related diseases.[10] This is typically a benefit which accrues with precinct or suburb level greening, rather than for an individual building. Given that the scale of this analysis is on individual building benefits, the incremental impact may be negligible.
Improved biodiversity	Green Infrastructure	Benefit with unclear materiality	Biodiversity benefits may arise from additional green cover being used to benefit fauna and flora. The nature of this benefit is likely to be highly context specific and similar to urban greening, would more likely occur with precinct/suburb level greening rather than for an individual building. Green infrastructure may also contribute to avoided costs to the extent that some councils can avoid costs of meeting canopy cover targets.

9 For example, Edwards, L. and Torcellini, P., *A Literature Review of the Effects of Natural Light on Building Occupants*, 2002, https://www.osti.gov/servlets/purl/15000841/

10 For example, U.S. Environmental Protection Agency (EPA), *Reduce Urban Heat Island Effect*, accessed from the U.S. EPA's website on 1 November 2021, https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect

2.5 Overarching CBA parameters and sensitivities

As previously stated, the CBA assesses impacts over time. This requires an appraisal period to be defined and the application of a discount rate (to account for the time value of money where a dollar today is worth more than a dollar in future). To enable comparison of the costs and benefits over time, as shown in **Table 5** this analysis:

- Applies a 20-year appraisal period which aligns with a likely useful life of a number of the design responses required to align with the Sustainability Planning Scheme Amendment.
- Includes a residual value to capture the benefits and costs of the assets with lives beyond the modelling period - Some interventions (such as external shading) may have an asset value of more than 20 years. Where this is the case there has been liaison with the technical ESD workstream to identify a likely useful life in order to place a residual value on these assets at the end of the appraisal period. The residual value is included in the analysis as a benefit (see **Box 3**). This is a standard approach in best practice CBAs.
- Applies a discount rate of 7% per year, consistent with the Victorian Department of Treasury and Finance.

Table 5: Overarching parameters for the CBA

Input	Value
Price base	2021
Appraisal start date	1 Jan 2023
Project appraisal period	20 years
Appraisal end date	1 Jan 2043
Discount rate	7% per annum

Source: Frontier Economics

As with any CBA, there are a number of uncertainties relating to the analysis. Sensitivity analysis was undertaken to analyse how the CBA results change if key parameters change. For this analysis, the following sensitivities were tested:

- Low discount rate: 4% per annum
- High discount rate: 10% discount rate
- Low benefits: -50% on all valuation factors
- High benefits: +50% on all valuation factors
- Residual value for external shading and green cover

Box 3: Base case costs and residual values

Base case costs

As previously stated, CBA is incremental in that it looks at additional costs and benefits over and above a "business as usual" scenario (the base case). For example, in this analysis for the RES-1 typology both the ESD Policy and non-ESD Policy base cases include a cost for a gas-fired central hot water system while the Sustainability Planning Scheme Amendment option includes a cost for an electric central hot water system. That is to say, there are differing upfront costs associated with different design responses and the analysis captures the incremental cost. The one design response which is treated differently is EV chargers, which form part of the Sustainability Planning Scheme Amendment option. Rather than assuming no EV chargers in the ESD Policy and non-ESD Policy base cases, the CBA assumes that EV chargers are retrofitted in the base case in 2030 – a point in the future when EV take up would be expected to be higher.

Residual values

As stated above, the project appraisal period is 20 years. This is intended to largely align with the useful life of the design responses in the Sustainability Planning Scheme Amendment option. It is understood that some elements may have longer useful lives. These can be captured in CBA through a residual value. The Department of Treasury and Finance's Economic Evaluation states that residual value at the end of the appraisal period should be "the lower of (a) the replacement cost or (b) the present value of the future stream of net benefits at the arbitrary earlier end of the project." Focussing on the two key cost items in a number of scenarios (external shading and green cover), these items do not have benefits that have been valued in the CBA. Hence, following the Department of Treasury and Finance's guidance means that the residual value of external shading and green cover should be zero. To understand how sensitive the CBA is to this approach, a sensitivity scenario has been undertaken where external shading and green cover are assumed to have a 40 year useful life which results in 50% of their upfront cost being a residual value benefit at the end of the CBA appraisal period (as with all impacts this is then subjected to discounting to reach a present value).

Source: Frontier Economics drawing on documents including Department of Treasury and Finance (2013), Economic Evaluation for Business Cases Technical guidelines.

3 Cost-Benefit Analysis Results

3.1 Results – central scenarios

The next step in the CBA process is to undertake an evaluation of the incremental economic, social, and environmental value of the options. The incremental future costs and benefits are discounted using a social discount rate to a 'net present value' (NPV) and and Benefit-Cost Ratios (BCRs) where:

- **NPV>0 and BCR>1** indicates that the option results in a net benefit to the community relative to the Base Case (i.e. incremental benefits of the option exceed incremental costs).
- **NPV = 0 and BCR=1** indicates that the incremental benefit of the option exactly equals its incremental costs.
- **NPV < 0 and BCR<1** indicates that the option results in a net cost to the community relative to the Base Case (i.e. incremental costs of the option exceed incremental benefits).

The high-level results of the CBA are presented in **Table 6** and **Table 7**. The overall finding from the CBA is that across the different typologies there are negative NPVs and BCRs less than one.

In interpreting these results it is important to note that we were unable to quantify a number of benefits where the magnitude of these benefits is difficult to ascertain. This is particularly the case for benefits associated with the indoor environment quality (IEQ) and green infrastructure (GI) themes. In the sections below we undertake a break-even analysis to provide some guidance on the magnitude of potential benefits from these themes to produce a BCR of 1.

When the costs and benefits from the IEQ and green infrastructure themes are removed from the CBA, the BCRs across typologies are close to or greater than 1. We show these BCRs in the bottom rows of **Table 6** and **Table 7** and throughout this results section.

The NON-RES 1 typology under the ESD base case had the most favourable result with a BCR of 0.64, or 1.41 when IEQ and GI themes are excluded. The Non-RES 2 with ESD Policy base case has the lowest BCR (0.09) while RES 1 with ESD Policy base case has the lowest NPV (-$1.3m). For Non-RES 2 with ESD Policy base case this result is a combination of having low incremental benefits compared to the ESD Policy base case and also having high costs – with the Green Cover design response comprising $220k or 83% of total costs in this scenario. For RES 1 with ESD Policy base case there are also high costs (with the Green Cover and external shading design responses making up $1.4m or 61% of the cost). However, this scenario also has high benefits which total around $1m.

Comparing the results for the same typology with an ESD Policy base case to the corresponding non-ESD Policy base case, the benefits are generally higher in the non-ESD Policy base case scenarios. This makes sense as in these scenarios the Sustainability Planning Scheme Amendment options provides a bigger increment in outcomes compared to the base case. However, this bigger increment also tends to come with a higher cost. The overall impact is the BCRs for the non-ESD Policy base case are higher than the corresponding ESD Policy base case for 5 of the 7 typologies with two base cases tested.

Table 6: Cost-benefit analysis results – ESD Policy base case

Typology	RES 1	NON-RES 1	RES 2	NON-RES 2	RES 3	NON-RES 3	RES 4
TOTAL BENEFITS ($)	1,077,281	294,643	23,089	22,890	36,369	30,671	170,127
TOTAL COSTS ($)	2,382,798	458,493	46,929	264,994	154,698	156,212	334,398
NET PRESENT VALUES ($)	-1,305,517	-163,850	- 23,840	- 242,104	- 118,329	- 125,541	- 164,271
BENEFIT-COST RATIO	0.45	0.64	0.49	0.09	0.24	0.20	0.51
BENEFIT-COST RATIO (IEQ AND GI EXCLUDED AS BENEFITS UNQUANTIFIED)	1.15	1.41	0.80	0.85	0.84	2.55	1.09

Source: Frontier Economics

Table 7: Cost-benefit analysis results – Non-ESD Policy base case

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4	RES 5
TOTAL BENEFITS ($)	1,182,124	470,315	32,179	65,061	41,877	52,911	142,610	7,646
TOTAL COSTS ($)	2,451,244	945,133	97,072	364,096	146,298	202,220	255,213	20,086
NET PRESENT VALUES ($)	-1,269,121	-474,818	-64,893	-299,035	-104,421	-149,309	-112,603	-12,440
BENEFIT-COST RATIO	0.48	0.50	0.33	0.18	0.29	0.26	0.56	0.38
BENEFIT-COST RATIO (IEQ AND GI EXCLUDED AS BENEFITS UNQUANTIFIED)	1.11	1.94	1.01	1.24	1.28	0.93	0.75	0.75

Source: Frontier Economics

Table 8 presents a breakdown of the NPVs by theme for the best and worst performing scenarios (in terms of the benefit-cost ratio) under the central case. A complete set of NPVs by theme are presented in Appendix A.

For the best performing scenario (NON-RES 1, ESD Policy), the Operational Energy, and sustainable transport themes have positive NPVs while the remaining themes have negative NPVs. The key cost streams relate to external shading and green cover.

For the worst performing scenario (NON-RES 2, ESD Policy), Circular Economy has a positive NPV, the operational energy, Sustainable Transport and Indoor Environment Quality have a negative NPV and green infrastructure has a very negative NPV. The Green Cover cost is the driver of the very negative NPV for the green infrastructure theme. The key benefits in this scenario relate embodied carbon reduction.

Table 8: Breakdown of Net Present Value by theme for best and worst performing scenarios (in dollars)

Typology	Best performing NON-RES 1, ESD Policy base case	Worst performing NON-RES 2, ESD Policy base case
OPERATIONAL ENERGY NPV	95,222	-314
SUSTAINABLE TRANSPORT NPV	11,936	-9,537
INTEGRATED WATER MANAGEMENT NPV	- 15,000	
INDOOR ENVIRONMENT QUALITY (IEQ) NPV	- 84,850	-18,800
CIRCULAR ECONOMY NPV	- 6,301	5,875
GREEN INFRASTRUCTURE (GI) NPV	- 164,856	-219,328

3.2 Sensitivity results

Sensitivity analysis looks at how results change with different key assumptions. **Table 9** and **Table 10** present the sensitivity results for the best and worst performing scenarios (from a benefit-cost ratio). A complete set of sensitivity results are presented in Appendix A.

It is no surprise to see that the sensitivities with low discount rate and higher benefits improve the results. A low discount rate means that the benefits which accrue over time are less heavily discounted in the analysis, which makes the benefits look better when compared to costs which are incurred upfront. The high benefits simply inflate the valuation factors which also make the benefits look better when compared to the costs. The opposite effect occurs in the high discount rate and lower benefits.

Notably, for both the best and worst performing scenarios, interpretation of the results does not change in the different sensitivity analyses. That is to say, both have a negative NPV and BCR less than 1 in all the sensitivities.

Table 9: Sensitivity results – best performing scenario (NON-RES 1, ESD Policy base case)

	4% discount rate	10% discount rate	Lower benefits - 50%	Higher benefits +50%	Residual values
TOTAL BENEFITS ($)	392,144	234,160	154,362	434,925	303,425
TOTAL COSTS ($)	512,383	424,191	372,029	544,956	458,493
NET PRESENT VALUES ($)	- 120,238	-190,031	- 217,667	-110,032	-155,068
BENEFIT-COST RATIO	0.77	0.55	0.41	0.80	0.66
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.49	1.34	1.26	1.47	1.41

Table 10: Sensitivity results – worst performing scenario (NON-RES 2, ESD Policy base case)

	4% discount rate	10% discount rate	Lower benefits - 50%	Higher benefits +50%	Residual values
TOTAL BENEFITS ($)	33,205	16,932	12,165	33,616	31,994
TOTAL COSTS ($)	265,036	264,967	264,929	265,059	264,994
NET PRESENT VALUES ($)	-231,831	-248,035	-252,764	-231,443	-233,000
BENEFIT-COST RATIO	0.13	0.06	0.05	0.13	0.12
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.23	0.63	0.45	1.25	0.85

3.3 Break-even analysis

As discussed above, reductions in urban heat leading to reduced urban-heat related disease burden is a potential benefit of the scenarios assessed as part of this CBA, and in particular for the IEQ and GI themes. Mitigating the range of damaging effects of the urban heat island effect is a rising policy and broader sustainability priority in Victoria and across Australia.

While the urban heat island effect can negatively impact a range of outcomes valued by the community, arguably the most critical of these is the impact of soaring temperatures on human health. There is now strong scientific evidence that high temperatures and heatwaves are driving substantial costs on society by causing heat-related disease and death. There are also direct financial costs to the health system associated with this impact, such as the cost of ambulance call-outs and emergency department treatments to address heat-related illness.

This suggests there may be merit in exploring the potential for alternative building standards to contribute to limiting the UHI effect my promoting or mandating the use of materials that do not add to urban heat or can reduce ambient temperatures. As discussed in Box 4, if alternative building standards can drive reductions in peak temperatures on very hot days and during heatwaves, then this temperature reduction can be linked to reductions in heat-related deaths and reductions in costs to the health system.

Box 4: Valuing the health benefits associated with a reduction in urban heat

- The first step is to understand the extent to which alternative building designs, materials, or other urban typology interventions can drive reductions in peak urban temperatures on hot days and during heatwaves. First it must be shown that this causal link exists, and then the magnitude of the impact must be measured.
- The second step is to understand the relationship between each degree of temperature reduction on a very hot day, the prevalence of heat-related illness and death, *and* the assumed population characteristics of the intervention area (ie. in the community where the alternative urban typologies or building standards are applied)
- If we can reasonably and robustly:

1. assume that the urban typology intervention does drive reductions in temperature
2. understand how much temperature reduction is likely
3. assume that the surrounding population that experiences that temperature reduction is sufficiently large and sufficiently similar to the general population, then,

   we can link urban temperature reduction to reductions in heat-related illness and heat-related death, and then can place a monetary value on the avoided deaths and on the avoided costs to the health system.

Source: Frontier Economics

3.3.1 Findings of our break-even analysis

Given the availability of information, our analysis:

- assumes interventions are capable of driving down peak ambient temperature on very hot days and during heatwaves to a sufficient extent such that interventions can be causally linked to avoided heat-related deaths
- only considers scenarios that are likely to affect the population most vulnerable to heat-related illness and death – the elderly and the young
- is based on larger scale residential scenarios only
- assumes that, if scaled, the local population has the same age and disease burden characteristics as the general population
- accounts for uncertainty of scenario design and typology impact – including a 50% additional buffer around scenario costs to ensure potentially additional costs of urban cooling are not excluded
- calculates the total value of additional urban cooling benefits, including the avoided social cost of death and the avoided financial cost to the health system associated with ambulance call-outs and emergency department treatments, required to achieve a BCR of 1 or NPV of zero for each scenario. This assumes all impacts are incremental to the base case

As shown in **Table 13**, the break-even analysis indicates that changes under the IEQ and GI themes could deliver value to the community (i.e. incremental benefits outweigh incremental costs), if the investments assessed reduced the rate of urban-heat related deaths by between 0.07 and 1.5 people over the modelling period (depending on the scenario assessed).

Table 11: Results of breakeven analysis: Indicative incremental avoided deaths notionally required to reach a scenario BCR of 1

Scenario	Additional avoided deaths required over 20 year modelling period to achieve BCR of 1[11]	Monetised benefit[12]
RES 1 - Inner Urban ESD Policy	0.78 – 1.5	$1,305,517 - $2,496,916
RES 1 - Suburban Non-ESD Policy	0.76 – 1.5	$1,269,121 - $2,494,743
RES 4 - Suburban ESD Policy	0.10 – 0.2	$164,271 – $331,471
RES 4 - Suburban Non-ESD Policy	0.07 – 0.14	$112,603 - $240,210

Source: Frontier Economics.

11 Figures assume each avoided death is incremental to the base case and that the profile of avoided deaths is constant over the 20 year modelling period

12 In $2020-21, discounted at 7%

However, it should be noted that this analysis does not purport to identify whether the scenarios assessed are likely to reduce the burden of urban heat related diseases to this extent.

As discussed above, whether this outcome is achievable (i.e. whether the option could deliver value) will depend on a range of site-specific characteristics, such as the scale of the investment, the affected population – in some cases options may deliver a significant enough reduction in urban heat to deliver the required reduction in disease burden (and thus deliver benefit to the community), in others they may not.

While further site-specific analysis is required to identify whether these projects can deliver significant urban-heat related benefits to the community, given our experience applying this framework to projects elsewhere, we note that:

- These benefits are most likely to be realised in areas that already suffer from high temperatures – the UHI and the potential impact of alternative building materials or additional tree canopy for urban cooling is highly site specific and sensitive to microclimate, prevailing wind patterns, and a large range of other factors.
- The analysis draws on previous studies that considered the combination of changes to urban building materials *in combination with* very large-scale planting of broad-leaf urban canopy to drive reductions in temperature, rather than just the impact of alternative urban typologies alone.
- Benefits will only be realised at scale, for a number of key reasons:
  - Only very large developments are likely to be able to influence the ambient temperature – this cannot robustly be a consistent, ongoing impact attributed to a single (even large building). Sophisticated modelling can determine the extent to which quite a large development can reliably lower the peak temperature.
  - Benefits analysed rely on the statistical comparability of the local population assumed to benefit from (ie. live amongst) the alternative urban typologies/building standards and the general population both in terms of the age distribution and the burden of disease. The benefits therefore can only be considered achievable at the scale of an entire community and not any individual building or cluster of buildings.

4 Conclusion

4.1 Summary of key results

A key finding of this CBA for the Sustainability Planning Scheme Amendment is that the quantified costs exceeded the quantified benefits across each typology.

Importantly, the identified value of these options does not consider the broad range of unmonetised social and environmental impacts. Our breakeven analysis indicates that these projects may deliver value to the community (i.e. incremental benefits outweigh incremental costs) where sufficient scale is achieved.

4.2 Lessons and potential next steps

The key lessons from this project are:

- Overall, the size of benefits (especially those related to reducing disease burden) are likely to be more achievable for larger projects (i.e. scale matters). While a 1.5 person reduction in disease burden per building may appear like a small change, in practice, given overall disease burden, achieving this reduction on a building by building approach may be difficult.
- The size of the benefit in practice will be dependent on a range of site-specific characteristics, including population affected, urban temperature, whether there is pre-existing infrastructure (for example bicycle paths).
- Dollar benefits are likely to be higher when a larger population is involved. The primary driver of the difference between the case study results is the number of people that they affect.
- In considering which types of impacts to quantify, more effort should be expended on those impacts which are likely to be more significant given the circumstances of each case (e.g. urban heat effects in hot regions) and for which there is a sound evidence base.

Importantly, this analysis has been undertaken for a range of indicative projects, rather than for individual projects with site-specific characteristics. In practice, the value of these options is likely to vary significantly depending on the specific intervention and its location. As such there is likely to be value in undertaking further, place-based analysis to identify the value of individual projects. In considering the development of individual projects, key lessons from this project would suggest there is benefit in:

- Undertaking further research on the site-specific value of benefits. This could include site-specific analysis of the change in outcomes or a site-specific study of the community's willingness to pay for improvements in environmental and social outcomes (for example, the willingness to pay for improved biodiversity).
- Broadening the scale of the project - i.e rather than undertake an assessment of a development by development basis, broaden the assessment to development-wide or precinct-wide if possible.
- Focusing on areas where projects can make a large difference, for example, those where:
  - Urban heat is a large problem, so reductions in urban heat are likely to have a comparatively larger impact

  - There is a large number vulnerable population (e.g. urban heat diseases impact the elderly and very young, and so reductions in urban heat diseases are most beneficial in areas with vulnerable populations)
  - There are constraints in the supply of services, such as energy, water and waste (e.g. there isn't space for the next landfill, so deferring the need for the next landfill site is likely to be more beneficial, than in an area where there is significant space for landfill)
- Identifying the distribution of costs and benefits, to aid in the funding of these investments. It is important to recognise that quantification of benefits does not equate to funding for those investments. While broader benefits may present opportunities to generate additional funding, such projects will not be dependent on securing such funding.

A Detailed results

Net Present Value by theme

Table 12: Breakdown of Net Present Value by theme – ESD Policy base case (in dollars)

Typology	Note	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4
OPERATIONAL ENERGY NPV		88,506	95,222	-9,548	-314	-16,026	9,809	23,187
SUSTAINABLE TRANSPORT NPV		-37,841	11,936	1,149	-9,537	-1,230	4,265	6,060
INTEGRATED WATER MANAGEMENT NPV		-44,799	-15,000			734	1,405	1,359
INDOOR ENVIRONMENT QUALITY NPV	(No benefits quantified)	-929,187	-84,850	-17,904	-18,800	-1,910	-10,360	2,926
CIRCULAR ECONOMY NPV		133,325	-6,301	2,463	5,875	9,662	3,159	-17,283
GREEN INFRASTRUCTURE NPV	(No benefits quantified)	-515,520	-164,856		-219,328	-109,560	-133,820	-180,520

Table 13: Breakdown of Net Present Value by theme – Non-ESD Policy base case (in dollars)

Typology	Note	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4	RES 5
OPERATIONAL ENERGY NPV		109,704	118,864	-9,141	-5,004	-2,605	9,043	-8,508	-6,462
SUSTAINABLE TRANSPORT NPV		-265,744	5,160	-1,466	-5,614	-976	-6,213	13,492	8
INTEGRATED WATER MANAGEMENT NPV		-53,220	20,260	3,357	-5,499	2,967	-19,023	156	
INDOOR ENVIRONMENT QUALITY NPV	(No benefits quantified)	-929,187	-292,200	-19,808	-18,800	-1,910	-26,560	-24,674	-9,921
CIRCULAR ECONOMY NPV		323,887	83,954	7,565	28,810	9,662	12,504	-51,030	3,935
GREEN INFRASTRUCTURE NPV	(No benefits quantified)	-454,560	-410,856	-45,400	-292,928	-111,560	-119,060	-42,040	0

Sensitivity analysis

Table 14:Cost-benefit results for low discount rate sensitivities – ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4
TOTAL BENEFITS	1,587,383	392,144	33,551	33,205	45,447	41,334	235,152
TOTAL COSTS	2,502,678	512,383	46,929	265,036	154,698	159,192	355,324
NET PRESENT VALUES	-915,295	-120,238	-13,378	-231,831	-109,251	-117,857	-120,172
BENEFIT-COST RATIO	0.63	0.77	0.71	0.13	0.29	0.26	0.66
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.50	1.49	1.16	1.23	1.05	2.75	1.33

Table 15: Cost-benefit results for low discount rate sensitivities – Non-ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4	RES 5
TOTAL BENEFITS	1,644,524	590,136	40,311	65,074	53,658	65,723	192,559	7,495
TOTAL COSTS	2,562,107	1,008,945	97,072	364,681	146,298	217,668	289,622	20,086
NET PRESENT VALUES	-917,583	-418,809	-56,761	-299,607	-92,640	-151,945	-97,062	-12,591
BENEFIT-COST RATIO	0.64	0.58	0.42	0.18	0.37	0.30	0.66	0.37
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.40	1.93	1.27	1.23	1.63	0.91	0.86	0.74

Table 16: Cost-benefit results for high discount rate sensitivities – ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4
TOTAL BENEFITS	780,960	234,160	17,056	16,932	26,356	24,288	131,398
TOTAL COSTS	2,310,152	424,191	46,929	264,967	154,698	154,315	321,196
NET PRESENT VALUES	- 1,529,192	-190,031	-29,873	-248,035	-128,342	-130,027	-189,798
BENEFIT-COST RATIO	0.34	0.55	0.36	0.06	0.17	0.16	0.41
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	0.9	1.34	0.59	0.63	0.61	2.4	0.91

Table 17: Cost-benefit results for high discount rate sensitivities – Non-ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4	RES 5
TOTAL BENEFITS	914,800	354,087	23,424	44,082	30,347	37,993	112,154	5,354
TOTAL COSTS	2,383,835	905,070	97,072	363,767	146,298	193,259	234,182	20,086
NET PRESENT VALUES	-1,469,035	-550,983	-73,647	-319,685	-115,951	-155,266	-122,029	-14,732
BENEFIT-COST RATIO	0.38	0.39	0.24	0.12	0.21	0.20	0.48	0.27
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	0.91	1.75	0.74	0.85	0.92	0.8	0.66	0.53

Table 18: Cost-benefit results for high benefits – ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4
TOTAL BENEFITS	1,375,906	434,925	31,273	33,616	46,769	43,004	238,823
TOTAL COSTS	2,543,875	544,956	46,929	265,059	154,698	161,359	365,972
NET PRESENT VALUES	-1,167,969	-110,032	-15,656	-231,443	-107,929	-118,355	-127,149
BENEFIT-COST RATIO	0.54	0.80	0.67	0.13	0.30	0.27	0.65
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.25	1.47	1.08	1.25	1.08	2.5	1.27

Table 19: Cost-benefit results for high benefits – Non-ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4	RES 5
TOTAL BENEFITS	1,566,286	647,680	42,256	74,303	54,102	64,862	193,831	8,374
TOTAL COSTS	2,601,722	1,040,108	97,072	364,715	146,298	220,328	302,634	20,086
NET PRESENT VALUES	-1,035,436	-392,427	-54,816	-290,412	-92,196	-155,466	-108,803	-11,712
BENEFIT-COST RATIO	0.60	0.62	0.44	0.20	0.37	0.29	0.64	0.42
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.29	1.92	1.33	1.4	1.65	0.87	0.82	0.82

Table 20: Cost-benefit results for low benefits – ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4
TOTAL BENEFITS	778,655	154,362	14,904	12,165	19,823	18,337	101,431
TOTAL COSTS	2,221,721	372,029	46,929	264,929	154,698	151,065	302,825
NET PRESENT VALUES	-1,443,065	-217,667	-32,025	-252,764	-134,875	-132,728	-201,394
BENEFIT-COST RATIO	0.35	0.41	0.32	0.05	0.13	0.12	0.33
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.0	1.26	0.51	0.45	0.46	2.66	0.8

Table 21: Cost-benefit results for low benefits – Non-ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4	RES 5
TOTAL BENEFITS	797,962	237,222	16,822	29,363	23,506	31,425	91,388	3,884
TOTAL COSTS	2,300,767	850,158	97,072	363,477	146,298	184,113	207,792	20,086
NET PRESENT VALUES	-1,502,805	-612,936	-80,250	-334,114	-122,792	-152,688	-116,403	-16,202
BENEFIT-COST RATIO	0.35	0.28	0.17	0.08	0.16	0.17	0.44	0.19
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	0.87	1.61	0.53	0.57	0.72	0.82	0.64	0.38

Table 22: Cost-benefit results for residual values – ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4
TOTAL BENEFITS	1,132,234	303,425	23,705	31,994	37,484	35,523	177,028
TOTAL COSTS	2,382,798	458,493	46,929	264,994	154,698	156,212	334,398
NET PRESENT VALUES	-1,250,563	-155,068	-23,224	-233,000	-117,214	-120,689	-157,370
BENEFIT-COST RATIO	0.48	0.66	0.51	0.12	0.24	0.23	0.53
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.15	1.41	0.8	0.85	0.77	2.55	1.09

Table 23: Cost-benefit results for residual values – Non-ESD Policy base case (in dollars)

Typology	RES 1	NON-RES 1	RES2	NON-RES 2	RES 3	NON-RES 3	RES 4
TOTAL BENEFITS	1,234,747	468,564	31,890	63,750	43,069	53,051	145,272
TOTAL COSTS	2,451,244	945,133	97,072	364,096	146,298	202,220	255,213
NET PRESENT VALUES	-1,216,497	-476,569	-65,182	-300,346	-103,229	-149,170	-109,941
BENEFIT-COST RATIO	0.50	0.50	0.33	0.18	0.29	0.26	0.57
BENEFIT-COST RATIO (IEQ & GI EXCLUDED)	1.11	1.83	0.93	0.99	1.18	0.85	0.75

B More information on benefit valuation

This appendix providers further information on our approach to valuing benefits in the CBA.

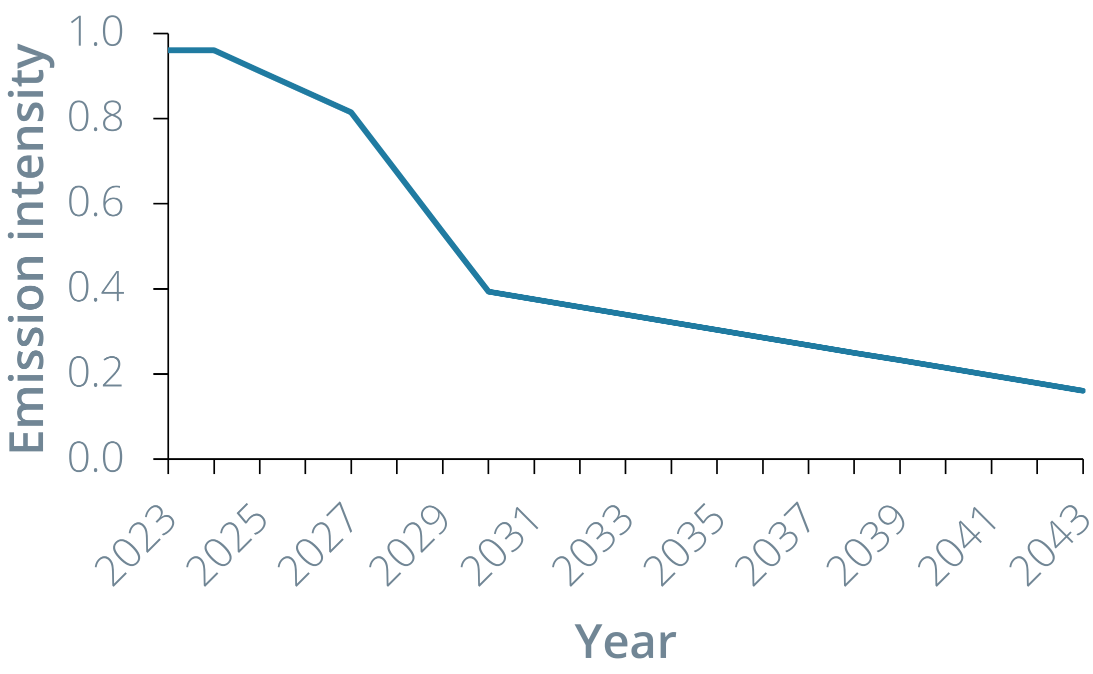
Avoided GHG emissions

Forecast emission intensity

As discussed in section 2.4, to estimate the value of avoided GHG emissions we have applied a forecast of the emission intensity of the Victorian electricity grid. The emission intensity of the grid is expected to fall over time as more renewable energy enters the market.

We have derived our forecasts from the Victorian Government's Victorian Energy Upgrades (VEU) program.[13] The VEU published forecast 10-year average emission intensity estimates. For example, the 10-year average emission intensity estimate for 2025 is 0.393 tonnes CO2-e/MWh. We have assumed this represents a reasonable point estimate for 2030. From 2030, we have assumed emission intensity tends towards zero in 2050 in line with the net zero commitment. Our forecast emission intensity is summarised in **Figure 5** below.

Figure 5: Forecast emission intensity (tCO2-e/MWh)



Source: Frontier Economics, based on Victorian Government commitments.

13 See, https://engage.vic.gov.au/victorian-energy-upgrades/targets, accessed 29 October 2021.

Reduction in energy use

In valuing reduced energy consumption, it is sometimes considered that the value should be based on the reduction in retail electricity bills experienced by customers as a result of reduced consumption. However, this conflates economic benefits with distributional impacts. For instance, because many retail costs of energy are fixed (i.e. don't vary with the volume of energy consumed), reducing these costs for some customers results in them being redistributed to other customers.

Our approach to valuing benefits from reduced energy use is based on the estimated resource cost savings for society. These include:

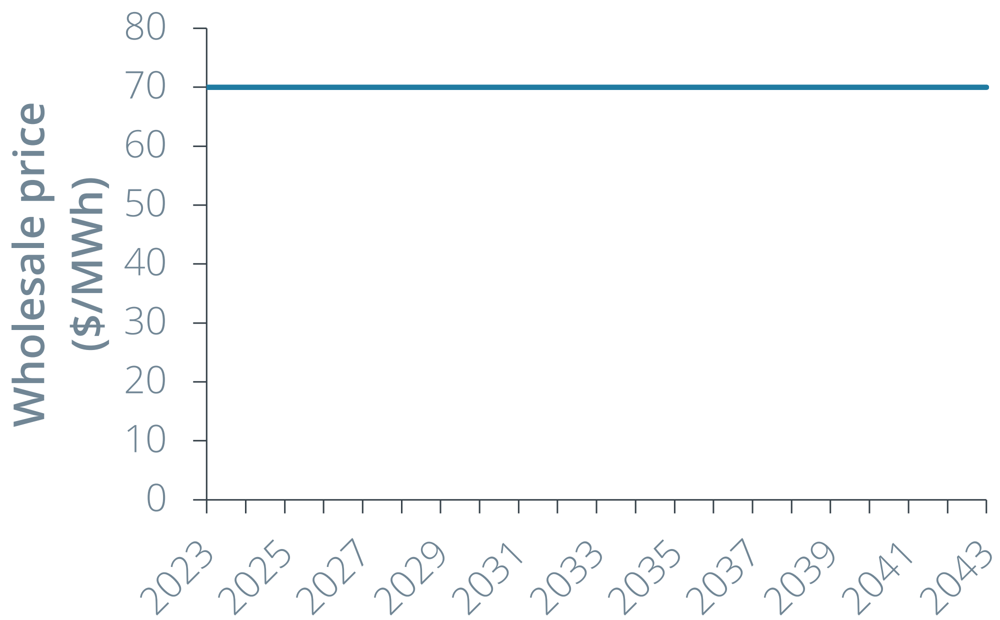
- variable costs avoided (estimated through wholesale market prices) and
- reduced capacity needed in the long run for electricity and gas network infrastructure.

Our approach is in line with guidance provided to the Australian Government for residential energy efficiency regulatory impact studies.[14]

Wholesale market prices

We have projected the wholesale electricity price will remain stable at $70/MWh ($0.07/kWh) as summarised **Figure 6**.

Figure 6: Wholesale electricity price projection ($/MWh)



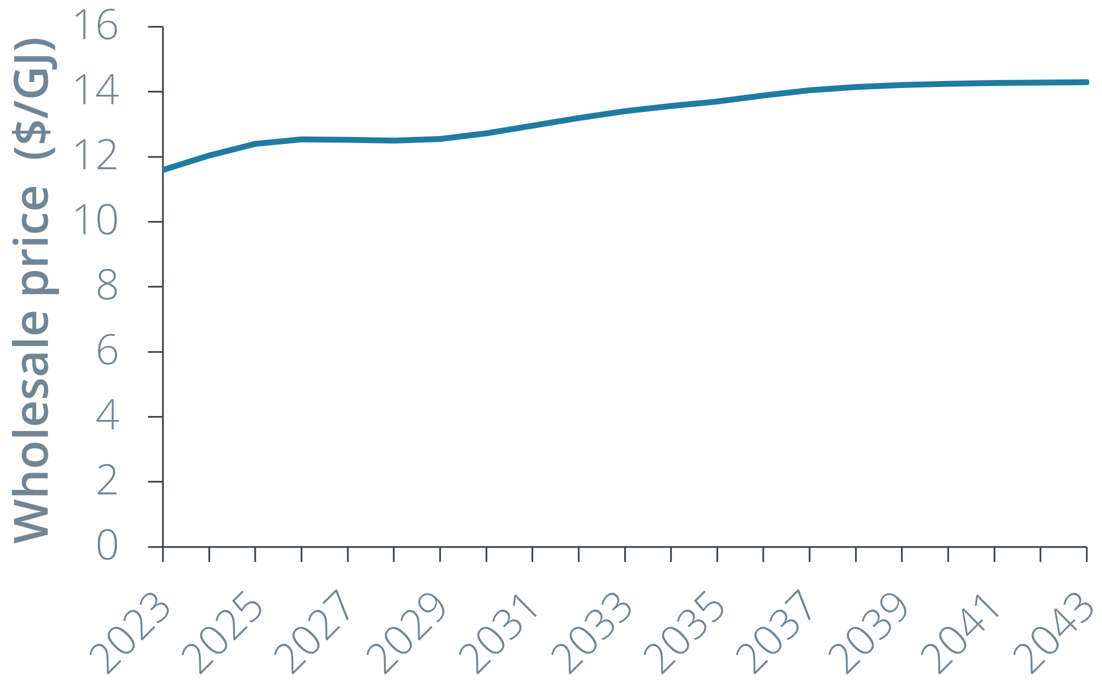
Source: Frontier Economics

Our forecast wholesale gas price is shown in **Figure 7** below. Our forecast derives from the Australian Energy Market Operators (AEMO's) 2022 Integrated System Plan (ISP). The ISP includes

14 Houston Kemp, *Residential Buildings Regulatory Impact Statement Methodology – Report to the Department of Environment and Energy*, 6 April 2017, pp13-14.

a modelling assumptions workbook with generator fuel prices. We have applied prices for new combined cycle gas turbine (CCGT) generation in Victoria, as individual generator prices may reflect some view on their legacy contracts. We consider that CCGT is closer to the system profile for gas demand, compared to open cycle gas turbine (OCGT).

Figure 7: Wholesale gas price projections ($/GJ)



Source: AEMO, 2022 Integrated System Plan – Modelling assumptions workbook

Network costs

A reduction in energy use means that over the longer run investment in new generation capacity may be deferred or avoided. The change in costs as a consequence of small changes in electricity or gas consumption are known as the long run marginal costs (LRMC). LRMC is a forward-looking concept and amounts to a measure of the additional cost incurred as a result of a relatively small increase in output, assuming all factors of production are able to be varied.

Estimates of LRMC are available for electricity network businesses in Victoria as part of their Tariff Structure Statements.[15] We converted residential LRMC ($/kilowatt/pa) into a single rate LRMC by dividing by the number of hours in a year. This produced an estimate of around $0.01/kWh.

For deferred gas network costs, we have adopted an estimate of $4.50/GJ based on a recent Consultation RIS undertaken by ACIL Allen. This estimate is based on forecast capital expenditure on augmentations in the most recent revenue determinations for each gas distributor and the forecast growth in demand from new connections.

15 For example, see https://jemena.com.au/documents/electricity/2021-2026_tariff-structure-statement.aspx

Avoided health costs of electricity generation

Electricity generation produces air pollution containing particulate matter, nitrogen oxides, sulphur dioxide, as well as other emissions. These can cause health problems such as respiratory illness and can also affect local economies.

We estimated the health benefits of reduced coal and gas-fired electricity using the studies referred to by ACIL Allen in the Consultation RIS for the National Construction Code 2022[16]. This resulted in avoided health damage costs of:

- $2.58/MWh for coal-fired generation
- $0.93/MWh for gas generation

We applied a weighted average of these values reflecting the share of coal (67.7%) and gas fired (4.5%) electricity generation in Victoria in 2020 ($1.78/MWh), declining over time as the rate as emission intensity discussed above.

Reduction in potable water use

We have valued reductions in potable water use brought about by elevated ESD standards based on LRMC. LRMC represents the cost of changing the capacity of a water supply system by building a permanent new supply source (such as a dam or a desalination plant). Water utilities use LRMC to decide if a water conservation activity is cheaper or more expensive than the cost of building a permanent augmentation to the water supply system. The LRMC applied in our analysis ($2,450/ML) is based on advice from Melbourne Water.

Avoided landfill / increased recycling

Estimates of reduced construction and demolition waste to landfill (tonnes) were multiplied by the full economic cost of landfill. To estimate the economic cost of landfill we:

- Reviewed published landfill gate fees for commercial and industrial waste and determined an indicative fee of $250/tonne (we placed more weight on metro rates given this is where most volume would be generated)
- Subtracted the current waste levy for industrial waste ($100/tonne) – average of metro and rural representing a financial transfer
- Added an estimate of externality costs of landfill representing visual disamenity ($1/tonne)[17]
- Subtracted an estimated recovery and processing cost for mixed concrete $43/tonne (including transport)[18]

16 ACIL Allen, National Construction Code 2022 Consultation Regulation Impact Statement for a proposal to increase residential building energy efficiency requirements, 20 September 2021, pp 90-21 https://acilallen.com.au/uploads/projects/377/ACILAllen_RISProposedNCC2022_2021.pdf

17 This estimate derives from the BDA Group, The full cost of landfill disposal in Australia, July 2009, see: https://www.awe.gov.au/sites/default/files/documents/landfill-cost.pdf

18 The estimate derives from Synergies Economic Consulting, Cost-benefit analysis of the implementation of landfill disposal bans in Queensland, November 2014, pp 27-29 https://www.synergies.com.au/wp-content/uploads/2019/09/cost-benefit-analysis-landfill-disposal-bans.pdf

- Added an estimated value of recovered materials for mixed concrete of $18/tonne)[19]

This approach provides an estimate of the avoided cost of landfill and value of recovered materials of $125/tonne.

[19] Ibid

C Literature review

Table 24: Literature review

Source	Topic	Key findings	Location
JONES, R. N., SYMONS, J. AND YOUNG, C. K. (2015) ASSESSING THE ECONOMIC VALUE OF GREEN INFRASTRUCTURE: GREEN PAPER. CLIMATE CHANGE WORKING PAPER NO. 24. VICTORIA INSTITUTE OF STRATEGIC ECONOMIC STUDIES, VICTORIA UNIVERSITY, MELBOURNE	Defining Green Infrastructure	Definitions of Green Infrastructure encompasses "blue" infrastructure, some definitions are linked to the functions of the Green infrastructure.	Australia, Victoria
	Value of Green Infrastructure	Non-use values are intangible values that have strong ethical component. They are important because once Green Infrastructure is removed, it is very hard to replace. Social benefits cover physical benefits (e.g. green infrastructure has been found to increase opportunities for recreation), social (e.g. green infrastructure has been found to reduce crime rates and improves patient recovery) and psychological and community-related benefits (e.g. green infrastructure has been found to enhance comfort).	Australia, Victoria
	Economic monetisation: Overview of methods	Some of the largest criticisms of individuals' willingness to pay approaches have come from behavioural economics. When asking what people would pay to gain, or not to lose or to gain a particular thing, Kahneman and Tversky, 1979, found that people valued the loss of something about twice as much as they valued obtaining the same thing. This was developed into prospect theory which states that people make decisions based on the potential value of losses and gains rather than the final outcome, and that people evaluate these losses and gains using certain heuristics, or rules of thumb.	Australia, Victoria

SYMONS, J., JONES, R.N., YOUNG, C.K. AND RASMUSSEN, B. (2015) ASSESSING THE ECONOMIC VALUE OF GREEN INFRASTRUCTURE: LITERATURE REVIEW. CLIMATE CHANGE WORKING PAPER NO 23. VICTORIA INSTITUTE OF STRATEGIC ECONOMIC STUDIES, VICTORIA UNIVERSITY, MELBOURNE	Economic monetisation: Applying these methods	Existing studies can be used (transferred) to estimate the economic value of changes stemming from other programmes or policies. In conducting an economic valuation with a benefits transfer, it is important to find the most appropriate studies to use in the benefits transfer exercise. However, the technique can also misjudge values by a factor of over 100% if not carried out with care (Rosenberger and Stanley, 2006).	Australia, Victoria
	Defining Green Infrastructure	There is no generally agreed definitions for Green Infrastructure. Some definitions are geared towards functionality of the Green Infrastructure and can be detailed to varying extents.	Australia, Victoria
	Value of Green Infrastructure	Identifies human well-being benefits as those arising from better access to green spaces increasing physical activity levels, increase in transport walking due land-use mix, better mental health due to regular contact with nature, etc. Environmental benefits include reductions in the urban heat island effect, carbon sequestration/storage and avoided emissions, air quality improvement, water cycle modification, flow control and flood reduction and water quality improvement and protection of Biodiversity (species diversity and population viability; habitat and corridors).	Australia, Victoria
	Economic monetisation: Applying these methods	A more sophisticated approach called the transfer function approach where the results from one study are adapted and modified to make it more suitable to another situation – for example making adjustments for location or socio-economic factors. However, the validity of the benefit transfer approach depends upon the rigour of the original study upon which it is based (ECOTEC, 2008) and the suitability of the target area for the transfer.	Australia, Victoria

BADIU, D., ET AL. (2019). "DISENTANGLING THE CONNECTIONS: A NETWORK ANALYSIS OF APPROACHES TO URBAN GREEN INFRASTRUCTURE"	Defining Green Infrastructure	Green Infrastructure definitions evolved over time from the concept of green spaces meant especially to improve the aesthetics of cities, before being associated with health and environmental benefits with the capacity to be connected and to provide several functions. Now, Green Infrastructure is part of larger concepts, such as ecosystem services and is a key element for providing a more healthier environment, for tackling challenges such as climate change, air pollution, water management and social injustice. The concepts associated with Green Infrastructure are determined by their relationship with society.	Global
WORLD HEALTH ORGANISATION (2016). "URBAN GREEN SPACES AND HEALTH: A REVIEW OF EVIDENCE"	Defining Green Infrastructure	There is no universally accepted definition of urban green space, with regard to its health and well-being impacts. Urban green spaces may include places with 'natural surfaces' or 'natural settings', but may also include specific types of urban greenery, such as street trees, and may also include 'blue space' which represents water elements ranging from ponds to coastal zones.	Global
	Value of Green Infrastructure	Green infrastructure can be associated with exposure to air pollutants, risk of allergies and asthma, exposure to pesticides and herbicides, exposure to disease vectors and zoonotic infections, accidental injuries, excessive exposure to UV radiation, vulnerability to crime. However, these detrimental effects are associated with poor maintenance of Green Infrastructure, and thus, can be reduced or prevented through proper planning, organisation and maintenance.	Global
TRANSPORT FOR NEW SOUTH WALES (TFNSW). "COST BENEFIT ANALYSIS GUIDE", (2019)	Benefit valuation: Valuation is more than monetisation of outcomes	Provides guidance on measuring benefits relating to active transport and environmental externalities. TfNSW publishes a set of economic parameters which reveals the estimated value of walking and cycling (in $/km) relating to various factors from accident cost to air pollution.	Australia, NSW

NSW HEALTH. "GUIDE TO COST BENEFIT ANALYSIS OF HEALTH CAPITAL PROJECTS", (2018)	Benefit valuation: Valuation is more than monetisation of outcomes	Prescribes guidance on measuring health benefits by service stream/scope and improvements in health outcomes, such as the use of the concept known as the disability-adjusted life year (DALY) to quantify health impact, as well as the valuing of health impact via reduced mortality or reduced morbidity.	Australia, NSW
NSW TREASURY. "GUIDE TO COST BENEFIT ANALYSIS", (2017)	Benefit valuation: Valuation is more than monetisation of outcomes	Sector-specific guidance on cost benefit analysis exists for coastal management, energy efficiency and mining and coal seam gas proposals.	Australia, NSW
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY ENVIROATLAS 18; URBAN ATLAS IN THE EUROPEAN UNION, 2011	Defining Green Infrastructure	A narrower approach defines Green Infrastructure as "all vegetated land, including agriculture, lawns, forests, wetlands, and gardens. Barren land and impervious surfaces such as concrete and asphalt are excluded." This is similar to "public green areas used predominantly for recreation such as gardens, zoos, parks, and suburban natural areas and forests, or green areas bordered by urban areas that are managed or used for recreational purposes"	USA
GHOFRANI ET AL., "A COMPREHENSIVE REVIEW OF BLUE-GREEN INFRASTRUCTURE CONCEPTS", (2017); HAMMER ET AL., "CITIES AND GREEN. GROWTH: A CONCEPTUAL FRAMEWORK", (2011)	Defining Green Infrastructure	Many sources consider Green Infrastructure in conjunction with Blue Infrastructure as an interconnected network of natural and designed landscapes. This includes waterways, wetlands, wildlife habitats greenways, parks, working farms, forests, which provide multiple functions. This definition is also extended in cases to include cemeteries, squares and plazas, and pathways and greenways.	Australia

VICTORIA STATE GOVERNMENT. "A FRAMEWORK FOR PLACE-BASED APPROACHES", (2020)	Economic monetisation methods: Economic monetisation	The idea of a place-based understanding or approach is one that targets the specific circumstances of a place and engage local people as active participants in development and implementation, requiring government to share decision-making. Place-based approaches can complement the bigger picture of services and infrastructure. They engage with issues and opportunities that are driven by complex, intersecting local factors and require a cross-sectoral or long-term response.	Australia, Victoria
INFRASTRUCTURE AUSTRALIA. "PLANNING LIVEABLE CITIES", (2018)	Economic monetisation methods: Economic monetisation	Cities require a greater focus on the holistic needs of communities and places, rather than on the services provided by individual sectors. This is particularly true in precincts where growth is occurring rapidly. Governments should therefore develop 'place-based' planning frameworks to ensure that the full range of infrastructure communities require, across sectors, is considered when planning for growth.	Australia
LOOMIS, J., (2011) "WHAT'S TO KNOW ABOUT HYPOTHETICAL BIAS IN STATED PREFERENCE VALUATION STUDIES?" JOURNAL OF ECONOMIC SURVEYS, 25, 363-370	Economic monetisation: Overview of methods	Stated and revealed preferences methods may work in market-like situations, but they cannot readily be extended to public goods, where the gain/loss bias increases up to 3:1.	General

GSOTTBAUER AND VAN DEN BERGH, "ENVIRONMENTAL POLICY THEORY GIVEN BOUNDED RATIONALITY AND OTHER-REGARDING PREFERENCES", (2011)	Economic monetisation: Overview of methods	Provides a useful and comprehensive survey of behavioural economics and environmental regulation summarising many of these issues. One study that asked people for their willingness to pay for services in urban green spaces and also asked for their perceived gains in wellbeing found that the results were mutually consistent (Dallimer et al., 2014), suggesting that such methods can be reliable when assessing personal benefit.	General
GILES-CORTI, B., ET AL. (2005). "INCREASING WALKING: HOW IMPORTANT IS DISTANCE TO, ATTRACTIVENESS, AND SIZE OF PUBLIC OPEN SPACE?" AMERICAN JOURNAL OF PREVENTIVE MEDICINE 28(2): 169-176.	Improved natural environments and active recreation	Found that access to proximate and large public open space with attractive attributes such as trees, water features and bird life is associated with higher levels of walking. Individuals with 'very good access' to public open space were 2.05 times as likely to use than those with very poor access. Those who used POS were 2.66x as likely to achieve recommended levels of physical activity (30min for 5 days). While accessibility was not significantly associated with achieving overall sufficient levels of activity, those with very good access to attractive and large public open space were 1.24-1.5 times more likely to achieve high levels of walking.	Australia, WA, Perth

BALL, K., ET AL. (2001). "PERCEIVED ENVIRONMENTAL AESTHETICS AND CONVENIENCE AND COMPANY ARE ASSOCIATED WITH WALKING FOR EXERCISE AMONG AUSTRALIAN ADULTS." PREVENTIVE MEDICINE 33(5): 434-440.	Improved natural environments and physical activity	Those reporting a moderately aesthetic environment were 16% less likely, and those reporting a low aesthetic environment were 41% less likely to walk for exercise relative to high aesthetic. Similarly – for moderately convenient 16% less likely and low convenience were 36% less likely to walk for exercise	Australia, NSW
GRIGSBY-TOUSSAINT, D. S., ET AL. (2011). "WHERE THEY LIVE, HOW THEY PLAY: NEIGHBORHOOD GREENNESS AND OUTDOOR PHYSICAL ACTIVITY AMONG PRESCHOOLERS." INTERNATIONAL JOURNAL OF HEALTH GEOGRAPHICS 10(1): 66.	Improved natural environments and physical activity	Higher levels of neighbourhood greenness as measured by the Normalized Difference Vegetation Index (NDVI) was associated with higher levels of outdoor playing time among preschool-aged children in our sample. Specifically, a one unit increase in neighbourhood greenness increased a child's outdoor playing time by approximately 3 minutes.	USA, Chicago, Illinois

BARTON, J. AND M. ROGERSON (2017). "THE IMPORTANCE OF GREENSPACE FOR MENTAL HEALTH." BJPSYCH. INTERNATIONAL 14(4): 79-81.	Physical activity and health outcomes	Incorporating green spaces into building architecture, healthcare facilities, social care settings, homes and communities will encourage physical activity (PA), which may lead to greater social interaction and wellbeing. Extra weekly use of the natural environment for PA reduces the risk of poor mental health by 6%	United Kingdom
ZAPATA-DIOMEDI, B., ET AL. (2018). "A METHOD FOR THE INCLUSION OF PHYSICAL ACTIVITY-RELATED HEALTH BENEFITS IN COST-BENEFIT ANALYSIS OF BUILT ENVIRONMENT INITIATIVES." PREVENTIVE MEDICINE 106: 224-230.	Physical activity and health outcomes Health outcomes and economic outcomes	They estimated the change in population level of PA attributable to a change in the environment due to the intervention. Then, changes in population levels of PA were translated into monetary values. Improvements in neighbourhood environments conferred estimated annual physical activity related health benefit worth up to $70 per person. Improving neighbourhood walkability was estimated to be worth up to $30 and improvements in sidewalk availability up to $22 per adult resident. Value of physical activity health related benefits of walking and cycling is $0.98 and $0.62 per kilometre respectively.	Australia

MARSELLE, M. R., ET AL. (2013). "WALKING FOR WELL-BEING: ARE GROUP WALKS IN CERTAIN TYPES OF NATURAL ENVIRONMENTS BETTER FOR WELL-BEING THAN GROUP WALKS IN URBAN ENVIRONMENTS?" INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH 10(11): 5603-5628.	Exposure to green space and mental health outcomes	Walking participants who frequently attended in green corridor spaces (-2.81) recorded significantly lower stress scores than those who walked in urban space.	England
BERMAN, M. G., ET AL. (2012). "INTERACTING WITH NATURE IMPROVES COGNITION AND AFFECT FOR INDIVIDUALS WITH DEPRESSION." JOURNAL OF AFFECTIVE DISORDERS 140(3): 300-305.	Exposure to green space and mental health outcomes	Working-memory capacity and positive affect improved to a greater extent after the nature walk relative to the urban walk. Interestingly, these effects were not correlated, suggesting separable mechanisms.	USA, Michigan
GILL, S. E., ET AL. (2007). "ADAPTING CITIES FOR CLIMATE CHANGE: THE ROLE OF THE GREEN INFRASTRUCTURE." BUILT ENVIRONMENT 33(1): 115-133.	Improved natural environments and UHI effect	The magnitude of the urban heat island effect can vary across time and space as a result of meteorological, locational and urban characteristics.	Global

NGIA (2012). MITIGATING EXTREME SUMMER TEMPERATURES WITH VEGETATION, NURSERY PAPERS 5, NURSERY AND GARDEN INDUSTRY AUSTRALIA. AVAILABLE AT: <HTTPS://WWW.NGIA.COM.AU/ATTACHMENT?ACTION=DOWNLOAD&ATTACHMENT_ID=1451>	Improved natural environments and UHI effect	Suburban areas are predicted to be around 0.5 degrees Celsius (C) cooler than the CBD, while a relatively leafy suburban area may be around 0.7 degrees C cooler than the CBD. A parkland (such as grassland, shrub-land and sparse forest) or rural area may be around 1.5 to 2 degrees C cooler than the CBD. Doubling the CBD vegetation coverage may reduce 0.3 degrees C ASDM temperature.	Australia, VIC, Melbourne
ADAMS, M. P. AND P. L. SMITH (2014). "A SYSTEMATIC APPROACH TO MODEL THE INFLUENCE OF THE TYPE AND DENSITY OF VEGETATION COVER ON URBAN HEAT USING REMOTE SENSING." LANDSCAPE AND URBAN PLANNING 132: 47-54.	Improved natural environments and UHI effect	Found that overall, increasing tree cover reduces average surface temperatures more dramatically than mixed vegetation cover. In a combined model of vegetation and other environmental factors, increase in 1 foliage projection cover (% of area covered by trees) decreases LST by 0.113 degrees C.	Australia, NSW, Sydney

CRCWSC (2016), IMPACTS OF WATER SENSITIVE URBAN DESIGN SOLUTIONS ON HUMAN THERMAL COMFORT, <HTTPS://WATERSENSITIVECITIES.ORG.AU/WP-CONTENT/UPLOADS/2016/07/TMR_B3-1_WSUD_THERMAL_COMFORT_NO2.PDF>	Improved natural environments and UHI effect	Research found trees can lower the Urban Thermal Climate Index by up to 10 degrees C reducing heat stress from 'very strong' to 'strong'.	Australia
SUSCA, T., ET AL. (2011). "POSITIVE EFFECTS OF VEGETATION: URBAN HEAT ISLAND AND GREEN ROOFS." ENVIRONMENTAL POLLUTION 159(8-9): 2119-2126.	Improved natural environments and UHI effect	The study monitored the urban heat island in four areas of New York City and found an average of 2 degrees C difference of temperatures between the most and the least vegetated areas, ascribable to the substitution of vegetation with man-made building materials.	United States, New York City

BOWLER, D. E., ET AL. (2010). "URBAN GREENING TO COOL TOWNS AND CITIES: A SYSTEMATIC REVIEW OF THE EMPIRICAL EVIDENCE." LANDSCAPE AND URBAN PLANNING 97(3): 147-155..	Improved natural environments and UHI effect	The average temperature reduction in the day was 0.94 degrees C between the urban temperature and the park temperature.	Spain, Italy, Mexico, Japan, Taiwan, Singapore, Sweden, Botswana, USA, Germany, Israel, Russia, Canada, UK and Greece
OLIVEIRA, S., ET AL. (2011). "THE COOLING EFFECT OF GREEN SPACES AS A CONTRIBUTION TO THE MITIGATION OF URBAN HEAT: A CASE STUDY IN LISBON." BUILDING AND ENVIRONMENT 46(11): 2186-2194.	Improved natural environments and UHI effect	Park cool island (PCI) effect was a median 1.5 degrees C difference between the surrounding atmospheric environment and the garden (ranging from 1 - 2.6 degrees C).	Portugal, Lisbon

VOELKER, S., ET AL. (2013). "EVIDENCE FOR THE TEMPERATURE-MITIGATING CAPACITY OF URBAN BLUE SPACE—A HEALTH GEOGRAPHIC PERSPECTIVE." ERDKUNDE: 355-371.	Improved natural environments and UHI effect	Concluded that the bluespaces studied could provide a cooling effect of 2.5 K on average. Wetlands showed the strongest effect (ΔT=5.2 K, min=4.8 K, max=5.6 K, n=2) and ponds the least (ΔT=1.6 K, min=0.4 K, max=4.7 K, n=6). Rivers showed a ΔT of 2.1 K (min=0.6 K, max=4 K, n=8), the unspecified urban blue space type “water” 2.5 K (min=0.5 K, max=3.4 K, n=5).	Portugal, Japan, Germany, China, Canada
SUN, R. AND L. CHEN (2017). "EFFECTS OF GREEN SPACE DYNAMICS ON URBAN HEAT ISLANDS: MITIGATION AND DIVERSIFICATION." ECOSYSTEM SERVICES 23: 38-46.	Improved natural environments and UHI effect	When there was green expansion minor decreases in LST were recorded at -1.11degrees C to -0.67 degrees C. Major increases in LST were recorded in areas of green loss (1.64-2.21degrees C)	China, Beijing
GILL, S. E., ET AL. (2007). "ADAPTING CITIES FOR CLIMATE CHANGE: THE ROLE OF THE GREEN INFRASTRUCTURE." BUILT ENVIRONMENT 33(1): 115-133.	Improved natural environments and UHI effect	Using the conurbation of Greater Manchester, investigation found that green infrastructure, specifically green rooftops, reduced surface temperature by 6.6 degrees between 1961-1990, making it an effective strategy to keep surface temperatures below the baseline level. Less vegetated surface areas will decrease evaporative cooling, whilst an increase in vegetative surface sealing results in increased surface runoff.	United Kingdom

ADAMS, M. P. AND P. L. SMITH (2014). "A SYSTEMATIC APPROACH TO MODEL THE INFLUENCE OF THE TYPE AND DENSITY OF VEGETATION COVER ON URBAN HEAT USING REMOTE SENSING." LANDSCAPE AND URBAN PLANNING 132: 47-54.	Improved natural environments and UHI effect	Increasing tree covers reduces average surface temperature significantly more than mixed vegetation cover. If an area with no vegetation was to be replaced by a typical parkland, land surface temperature would be reduced by 3.48 degrees C	Australia, Sydney

NSW OFFICE OF ENVIRONMENT AND HERITAGE (2015). URBAN GREEN COVER IN NSW: TECHNICAL GUIDELINES, NSW GOVERNMENT. AVAILABLE AT: <HTTPS://CLIMATECHANGE.ENVIRONMENT.NSW.GOV.AU/-/MEDIA/NARCLIM/FILES/SECTION-4-PDFS/URBAN-GREEN-COVER-TECHNICAL-GUIDELINES.PDF?LA=EN&HASH=C7FCADABE417DD2DF67461F067463054D9408E2F>	Improved natural environments and UHI effect	Dark, impervious surfaces can absorb solar energy, causing the temperature of the city to rise as much as 10-20 degrees C higher than surrounding air temperatures. Every 10% increase in tree cover can reduce land surface temperatures by more than 1 degree Celsius. This means that a 14% increase in tree cover would offset this thermal loading effect	Australia, NSW

LOUGHNAN, M. E., ET AL. (2010). "THE EFFECTS OF SUMMER TEMPERATURE, AGE AND SOCIOECONOMIC CIRCUMSTANCE ON ACUTE MYOCARDIAL INFARCTION ADMISSIONS IN MELBOURNE, AUSTRALIA." INTERNATIONAL JOURNAL OF HEALTH GEOGRAPHICS 9(1): 41.	UHI effect and health outcomes	Positive association between AMI admission to hospital and age and socioeconomic inequality. Residents from highest or lowest socioeconomic standing more likely to be admitted for AMI; younger people most likely to be admitted.	Australia, Melbourne

PHUNG, D., ET AL. (2016). "AMBIENT TEMPERATURE AND RISK OF CARDIOVASCULAR HOSPITALIZATION: AN UPDATED SYSTEMATIC REVIEW AND META-ANALYSIS." SCIENCE OF THE TOTAL ENVIRONMENT 550: 1084-1102.	UHI effect and health outcomes	The pooled results suggest that for a change in temperature condition, the risk of cardiovascular hospitalization increased 2.8% for cold exposure, 2.2% for heatwave exposure, and 0.7% for an increase in diurnal temperature. No association was observed for heat exposure. Effects did change when incorporating variation of effect sizes: 7.8% for cold exposure, 1% for heat exposure, 6.1% for heatwave exposure, and 1.5% for an increase in diurnal temperature.	Germany, South Korea, Greece, UK, Taiwan, Australia, China, Portugal, Japan, USA, Vietnam, Mozambique, Czech Republic, Denmark, Thailand, Italy, Lithuania, Slovenia, France and Russia

MUELLER, N., ET AL. (2016). "URBAN AND TRANSPORT PLANNING RELATED EXPOSURES AND MORTALITY: A HEALTH IMPACT ASSESSMENT FOR CITIES." ENVIRONMENTAL HEALTH PERSPECTIVES 125(1): 89-96.	UHI effect and health outcomes	Reducing heat by 4 degrees prevents 376 deaths, increasing life expectancy by 34 days.	Barcelona, Spain
YE, X., ET AL. (2011). "AMBIENT TEMPERATURE AND MORBIDITY: A REVIEW OF EPIDEMIOLOGICAL EVIDENCE." ENVIRONMENTAL HEALTH PERSPECTIVES 120(1): 19-28.	UHI effect and health outcomes	The majority of studies reported a significant relationship between ambient temperature and total or cause-specific morbidities. However, there were some inconsistencies in the direction and magnitude of nonlinear lag effects. The majority of studies reported detrimental effects of heat on the same day or up to the following 3 days.	USA, Canada, Japan, Taiwan, Australia, Greece, Spain, South Korea, UK, Switzerland and Italy

XU, Z., ET AL. (2012). "IMPACT OF AMBIENT TEMPERATURE ON CHILDREN'S HEALTH: A SYSTEMATIC REVIEW." ENVIRONMENTAL RESEARCH 117: 120-131.	UHI effect and health outcomes	The existing literature indicates that very young children, especially children under one year of age, are particularly vulnerable to heat-related deaths. Hot and cold temperatures mainly affect cases of infectious diseases among children, including gastrointestinal diseases and respiratory diseases. Pediatric allergic diseases, like eczema, are also sensitive to temperature extremes. During heat waves, the incidences of renal disease, fever and electrolyte imbalance among children increase significantly.	Peru, Malta, Japan, Germany, UK, Bangladesh, Burkina Faso, Australia, Spain, Greece, Taiwan, USA, Cameroon and Singapore
CENTER FOR DISEASE CONTROL AND PREVENTION (2006), HEAT ISLAND IMPACTS, VIEWED JANUARY 2018, <HTTPS://WWW.EPA.GOV/HEAT-ISLANDS/HEAT-ISLAND-IMPACTS#3>	UHI effect and health outcomes	Estimates that from 1979–2003, excessive heat exposure contributed to more than 8,000 premature deaths in the United States	United States

KABISCH, N., ET AL. (2017). "THE HEALTH BENEFITS OF NATURE-BASED SOLUTIONS TO URBANIZATION CHALLENGES FOR CHILDREN AND THE ELDERLY–A SYSTEMATIC REVIEW." ENVIRONMENTAL RESEARCH 159: 362-373.	UHI effect and health outcomes	Kabisch, van den Bosch and Lafortezza (2017) found that urban trees and other vegetation provides cooling through shade and evaportranspiration, which reduce the impact of the UHI on hot summer days	Global
KJELLSTROM, T. AND H. J. WEAVER (2009). "CLIMATE CHANGE AND HEALTH: IMPACTS, VULNERABILITY, ADAPTATION AND MITIGATION." NEW SOUTH WALES PUBLIC HEALTH BULLETIN 20(2): 5-9.	UHI effect and health outcomes	Heat island effect contributes to greater heat exposure, which is positively associated with morbidity and mortality; mortality increases at temperatures above 28 degrees C, particularly amongst people 65+ years.	Australia, ACT

PERČIČ, S., ET AL. (2018). "NUMBER OF HEAT WAVE DEATHS BY DIAGNOSIS, SEX, AGE GROUPS, AND AREA, IN SLOVENIA, 2015 VS. 2003." INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH 15(1): 173.	UHI effect and health outcomes	People over 75 years and those with pre-existing acute circulatory diseases are most heavily impacted by heatwave. Risk factors of hypertension include being overweight and sedentary lifestyle. Older people with physiological cardiovascular impairment are more sensitive to heat waves	Slovenia
SMITH, K. R. AND P. J. ROEBBER (2011). "GREEN ROOF MITIGATION POTENTIAL FOR A PROXY FUTURE CLIMATE SCENARIO IN CHICAGO, ILLINOIS." JOURNAL OF APPLIED METEOROLOGY AND CLIMATOLOGY 50(3): 507-522.	UHI effect and urban environments	Widespread adoption of vegetated roofs could reduce localised temperatures up to 3 degrees C, but the effect is similar to other technologies (e.g. white roofs). The green roof approach also has several limitations including that the reduced temperature reduces natural circulation at the warmest times. Though this could reduce pollutants in the city, it also reduces natural cooling.	USA
ZANDER, K. K., ET AL. (2015). "HEAT STRESS CAUSES SUBSTANTIAL LABOUR PRODUCTIVITY LOSS IN AUSTRALIA." NATURE CLIMATE CHANGE 5(7): 647.	Health outcomes and economic outcomes	Estimated productivity may decrease by 11-27% in hot regions by 2080, and by 20% globally in hot months by 2050. Annual economic burden estimated to be US$6.2b for Australian workforce.	Australia

KJELLSTROM, T. AND H. J. WEAVER (2009). "CLIMATE CHANGE AND HEALTH: IMPACTS, VULNERABILITY, ADAPTATION AND MITIGATION." NEW SOUTH WALES PUBLIC HEALTH BULLETIN 20(2): 5-9.	Health outcomes and economic outcomes	Positive association between direct heat exposure and labourer's ability to carry out physical work, increased absenteeism and reduced labour productivity	Australia, ACT
GREEN BELT (2015). THE IMPACT OF GREEN SPACE ON HEAT AND AIR POLLUTION IN URBAN COMMUNITIES: A META-NARRATIVE SYSTEMATIC REVIEW. THE DAVID SUZUKI FOUNDATION. AVAILABLE AT: <HTTPS://DAVIDSUZUKI.ORG/WP-CONTENT/UPLOADS/2017/09/IMPACT-GREEN-SPACE-HEAT-AIR-POLLUTION-URBAN-COMMUNITIES.PDF>	Improved natural environments and UHI effect Improved natural environments and air quality	Among the identified studies on green space and air pollution, 92% reported pollution mitigating effects, Among studies on heat mitigation, 98% reported urban cooling effects associated with green space	USA, China, Japan, UK, Italy, Greece, Germany, Canada

VAN DEN BOSCH, M. AND Å. O. SANG (2017). "URBAN NATURAL ENVIRONMENTS AS NATURE-BASED SOLUTIONS FOR IMPROVED PUBLIC HEALTH–A SYSTEMATIC REVIEW OF REVIEWS." ENVIRONMENTAL RESEARCH 158: 373-384.	Improved natural environments and all health risk factors All health risk factors and health outcomes	Increase in natural green space accessibility strongly associated with increased physical activity, with greatest benefit being reduced cardio-vascular disease (CVD) risk and related mortality. Inconclusive association between obesity as an outcome of physical inactivity but strong evidence of association between obesity and CVD, and obesity and mental disorders. Strong association between physical activity and reduced levels of anger and sadness. Association between excess heat and disease susceptibility due to reduced 'adaptation capacity of human thermoregulation' (may exacerbate existing chronic conditions). Moderate to strong evidence of positive association between green space and all-cause mortality	Global
OFFICE OF BEST PRACTICE REGULATION (2014). BEST PRACTICE REGULATION GUIDANCE NOTE VALUE OF STATISTICAL LIFE. AUSTRALIAN GOVERNMENT DEPARTMENT OF THE PRIME MINISTER AND CABINET. AVAILABLE AT: <HTTPS://WWW.PMC.GOV.AU/SITES/DEFAULT/FILES/PUBLICATIONS/VALUE_OF_STATISTICAL_LIFE_GUIDANCE_NOTE.PDF >	Health outcomes and economic outcomes	WTP method is most appropriate for measuring the value of statistical life (reductions in the risk of physical harm). WTP involves identifying how much a consumer would pay for products that reduce/mitigate the risk of death or serious injury	Global

ABELSON, P. (2008). ESTABLISHING A MONETARY VALUE FOR LIVES SAVED: ISSUES AND CONTROVERSIES. OFFICE OF BEST PRACTICE REGULATION. AVAILABLE AT: <HTTPS://WWW.PMC.GOV.AU/SITES/DEFAULT/FILES/PUBLICATIONS/WORKING_PAPER_2_PETER_ABELSON.PDF>	Health outcomes and economic outcomes	VSL from studies ranged from A$3m to A$15m. Paper suggests that public agencies in Australia adopt a VSL of $3.5m for avoiding an immediate death of a healthy individual in middle age (about 50) or younger; a constant VLY of $151 000 which is independent of age; and age-specific VSLS for older persons equal to the present value of future VLYs of $151,000 discounted by 3% per annum.	Australia
ACCESS ECONOMICS (2007). THE HEALTH OF NATIONS: THE VALUE OF STATISTICAL LIFE. AUSTRALIAN SAFETY AND COMPENSATION COUNCIL. AVAILABLE AT: <HTTPS://WWW.SAFEWORKAUSTRALIA.GOV.AU/SYSTEM/FILES/DOCUMENTS/1702/THEHEALTHOFNATIONS_VALUE_STATISTICALLIFE_2008_PDF.PDF>	Health outcomes and economic outcomes	While VSL is somewhat flawed as a concept to capture the value of health life, WTP approach to valuing human life have been the focus of the literature in this area since the 1960s. Revealed preference studies are generally considered superior to stated preference methods in revealing WTP as they are based on real world empirical binding market transactions. A literature review suggests a mean VSL in Australia of $5.7m and a median of $2.9m.	Global

ORGANISATION FOR ECONOMIC COOPERATION & DEVELOPMENT 2012, THE VALUATION OF MORTALITY RISK, MORTALITY RISK VALUATION IN ENVIRONMENT, HEALTH AND TRANSPORT POLICIES, OECD PUBLISHING. AVAILABLE AT: <HTTP://WWW.OECD.ORG/ENVIRONMENT/MORTALITYRISKVALUATIONINENVIRONMENTHEALTHANDTRANSPORTPOLICIES.HTM>	Health outcomes and economic outcomes	While in some cases, a new primary valuation study, tailored for the specific policy in question, might be needed in order to carry out an appropriate CBA, in many situations benefit transfer (where VSL values that have been estimated in one context are– with appropriate adjustments – used in policy assessments in another context) will generally be less time- and resource-consuming. Average adult VSL for OECD countries ranges between US $1.5m-4.5m, with a base value of US $3m.	Global
VISCUSI, W. K. AND J. E. ALDY (2003). "THE VALUE OF A STATISTICAL LIFE: A CRITICAL REVIEW OF MARKET ESTIMATES THROUGHOUT THE WORLD." NATIONAL BUREAU OF ECONOMIC RESEARCH WORKING PAPER SERIES 9487.	Health outcomes and economic outcomes	Median value of VSL of prime-aged workers is $7m Income elasticity of VSL ranges from 0.5 to 0.6	USA

JORDAN. H, DUNT ET. AL (UNDATED). MEASURING THE COST OF HUMAN MORBIDITY AND MORTALITY FROM ZOONOTIC DISEASES. AUSTRALIAN CENTRE OF EXCELLENCE FOR RISK ANALYSIS. AUSTRALIA. AVAILABLE AT: <HTTPS://CEBRA.UNIMELB.EDU.AU/__DATA/ASSETS/PDF_FILE/0008/2220875/1002BOID1FR.PDF>	Health outcomes and economic outcomes	Must consider burden of disease as when measuring consequences of illness; must consider single or multi-criteria approach, use of data, time and resources available, contribution of modelling and equity consideration when measuring economic costs WTP method may be warranted if intangible costs are important. Review recommends use of Cost of Illness method to measure economic costs of human morbidity and mortality	Australia
MARKEVYCH, I., ET AL. (2017). "EXPLORING PATHWAYS LINKING GREENSPACE TO HEALTH: THEORETICAL AND METHODOLOGICAL GUIDANCE." ENVIRONMENTAL RESEARCH 158: 301-317.	Improved natural environments and health outcomes	Green spaces have 3 functions: reducing harm (air pollution, noise reduction, heat reduction), restoring capacities (attention and focus restoration) & building capacities (encouraging physical activity & facilitating social cohesion). These functions may lead to improving physical health & wellbeing (self-perceived health, higher birth weight, lower BMI, lower risk of depression and cardiovascular disease)	Global

Source: Frontier Economics

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