Victoria Institute of Strategic Economic Studies

Assessing the Economic Value of Green Infrastructure: Green Paper

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Executive summary

This green paper discusses the economic aspects of valuing green infrastructure at the local government scale. Supported by funding provided by the Government of Victoria, and led by the City of Melbourne, Victoria University is developing an economic framework for green infrastructure in collaboration with four local government bodies: the Cities of Banyule, Kingston, Melbourne and Moonee Valley.

Green infrastructure includes parks and reserves, backyards and gardens, waterways and wetlands, greenery on streets and transport corridors, pathways and greenways, squares and plazas, roof gardens and living walls, sports fields, and cemeteries.

The project aims to:

> *Produce an economic framework to value the benefits of green infrastructure in order to develop the business case for adapting now. As much as is feasible, the project will explore the multiple benefits of green infrastructure in order to develop an understanding of potential returns on investment by adapting urban environments at the local government scale. The ultimate goal of the project is to put investment in green infrastructure at the local government level on a more even footing with investment in grey infrastructure.*

This paper discusses the economic issues informing framework construction in covering the following topics:

- The nature of Greater Melbourne, emphasising the early establishment of green open space, parks and gardens and how that has defined the city's character.
- The concept of green infrastructure is contrasted with conventional infrastructure, outlining similarities, differences and interactions.
- The concept of total economic value (TEV) associated with environmental good and services.
- The major differences between environmental and ecological economics and how they apply to green infrastructure.
- The methods and tools used to value the benefits of green infrastructure.

Conventional economics is not well suited to valuing green infrastructure because of its need to convert a diverse range of values into dollars. The economic literature and practice has many different views about how non-market values should be managed, some of which are suitable for valuing various aspects of green infrastructure. The findings in the paper contribute to a number of recommendations informing how a framework for valuing green infrastructure may be constructed.

The nature of Melbourne

Melbourne's natural and human history describes Melbourne as a meeting place of natural and human systems, both Indigenous and European. When Europeans landed in Port Phillip Bay, they found a country that was park-like and pleasing to European eyes, having been greatly shaped by Aboriginal land-use. The grand parks designed around inner Melbourne formalised this legacy by establishing Victorian parks and gardens, and promoting the natural sciences in the form of the

Botanical Gardens and Observatory. By the late 19th century, the sell-off of public parks was prevented by public protest, establishing a political legacy that survives to this day.

The outer urban areas were not so fortunate. Wetlands were drained and prized landscapes built over. Creeks were turned into cement drains to control flooding. This process is now being reversed as important areas are being reclaimed and rehabilitated. Research into urban ecology is providing the knowledge on how to deliver a wide range of values to the community. Ecosystem services are now being recognised as important for climate change adaptation, while urban green infrastructure in general is increasingly being seen as an important contributor to Melbourne's liveability. The integration of natural, Indigenous, European and multicultural heritage into a post-industrial future is still very rudimentary but progressing.

Summary of green infrastructure benefits

Green infrastructure (GI) benefits provided by ecosystem goods and services are divided into three main groups:

1. Economic benefits
Green infrastructure contributes to the economy via the direct supply of goods and services. The indirect benefits to the economy are many but hard to quantify. By improving amenity, GI can increase property values and improve consumer activity in some precincts. Ecosystem services also provide a 'free service' that can support other economic activities such as recreation, sport and tourism. In some cases, it may provide the basis for such activities (e.g., ecotourism).

2. Social benefits
Social benefits are diverse and often hard to measure as many are indirect, such as community identity, amenity and equity. Health benefits include mental, physical and spiritual health. The provision of clean air and water, and places to walk and exercise provide the basis for improved community welfare. Green infrastructure can also help connect communities through social activities in public spaces.

3. Environmental benefits
Environmental benefits contribute directly to environmental protection or to improvements in environmental health that may indirectly contribute to social and economic benefits. Direct benefits include healthy ecosystems, healthy populations of flora and fauna, connectivity of different spaces, and structure that promotes and protects species diversity. The ecological resilience created by healthy ecosystems also supports the overall resilience of a place to environmental extremes.

Valuing green infrastructure

The total economic value (TEV) of the broader environment was originally developed because by only considering the dollar benefits of development, harm to people and the environment was being ignored, which led to investments that may not have been undertaken had the harmful effects been considered. In this capacity, TEV was used to negate potential harm. However, TEV is now being applied in a positive sense to provide new ecosystem services in areas where they are lacking or where additional services can improve human and environmental health and welfare.

TEV includes both use and non-use values. Non-use values include provision of future environmental options and existence values. These are intangible values that have a strong ethical component. They are important because once green infrastructure is removed, it is very hard to replace, a cost that is rarely accounted for in cost-benefit analyses. The combination of very different values ranging from dollars to ethics under the umbrella of TEV disallows the calculation of a single total economic value. The TEV concept is therefore best for classifying and accounting for ecosystem services and identifying the values they contribute to, but should not be used to add all those values into a single number. Comprehensive economic value is a better term because it can accommodate a variety of measures that are both quantitative and qualitative.

Environmental and ecological economics have important differences, especially regarding how they consider the weak and strong substitutability of ecosystem goods and services. Environmental economics considers that environmental and manufactured services are largely substitutable. That is, if an environmental service is removed, the economy can replace it; perhaps not one to one, but in an economically feasible way. It also takes the lead from orthodox economics in calculating marginal change in human utility as the primary measure of benefit. This assumes that people want things but don't care where they come from and are comfortable substituting one need for another.

Ecological economics looks at the total value of an asset and what it produces, including intangibles. It assumes that human needs cannot be collapsed into a single measure of utility, taking a much more philosophical approach to value. It does so by combining science and economics. Science plays a key role in identifying levels of substitutability, critical thresholds, biodiversity values and ecological health. The loss of a significant ecosystem, or a species, is considered to have an ethical importance on a par with the human right to existence. Qualitative to quantitative methods are used to value various aspects of green infrastructure, depending on the weighting between utility (material goods and services) and intangible, especially intrinsic, value.

These values are exercised on three levels, each requiring different methods of valuation:

- At the individual level, expanded cost-benefit analysis can be used to assess benefits in market and market-like situations. This can include willingness to pay, willingness to avoid loss and benefit transfer methods if used where suitable.
- At the community level, community and intrinsic values are best assessed using deliberative democracy-type approaches rather than adapting methods suited to market analysis.
- At the institutional level, formal and informal rules direct local government and set the framework for how valuation is carried out and applied.

Aggregating goods and services

Goods and services are exclusive if they are personal and consumptive, and non-exclusive if shared and non-consumptive. Exclusive goods can be used or consumed by one person, whereas air and views are non-exclusive because they are shared. All four combinations of public/private and consumptive/non-consumptive are possible. Many of the goods and services provided by GI are non-exclusive, but may be limited because only a certain number of people can enjoy them before they become over-exploited.

The most important aspect of a public good is often quality rather than quantity. For example, high quality parkland provides a much greater level of services, has higher visitation rates and contributes both public and private benefits in the form of higher surrounding property prices, than does a paddock with a bit of grass.

Demand for social benefits can be allocated to individuals or to the community depending on context. Conventional economic approaches aggregate individual preferences and apply those to cost-benefit methods. Community values are shared preferences, considered to be different to the sum of individual preferences. They are based on relationships that include trust, reciprocity and shared values, and are mostly intangible. Tools for estimating community values are not well developed and often there is no single or correct answer. Ethical considerations of fairness and justice are also important. This project is treating individual and community benefits separately. Care must be taken to avoid double counting, so the test used to distinguish these different types of benefit is whether a group that benefits from a good or service could be any group of individuals or whether that benefit is unique to a community.

Asset valuation

Classes, subclasses and types of green infrastructure can be based on those developed for local government for conventional infrastructure by adapting them to account for the different types of green infrastructure. Assets can also be linked to the delivery of goods and services by using an asset valuation and maintenance program that addresses infrastructure development, maintenance, upkeep and replacement. These are linked to specific service levels. By adopting life cycle investment, an asset management program can focus on sustainable service delivery.

Valuing green growth

The main differences between green infrastructure and conventional infrastructure are:

- The high proportion of intrinsic value to total value.
- A large contribution to social and environmental values rather than conventional economic values.
- The relatively low substitutability of some assets.
- The biological aspect of growing assets, goods and services.
- Its long-lived nature and maintenance of value over long time periods.

Discounting is used to ask two main questions:

- What is the value of doing this now as compared to later? and
- Which of the options on the table provides the best return over time?

Discounting does two main things:

1. It takes the basic human preference for having something now compared to later.
2. It allows for the present value of future returns to be contrasted with the up-front investment costs and upkeep.

The results calculate net present value of an up-front investment with the flow of returns over time, discounted by a percentage for each unit of time, usually a year. Benefits can be expressed as dollars, from an ethical perspective, or a combination of both. The social discount rate is the rate applied to public investment expected to produce some form of social return.

Australia's recommended social discount rate of 7% is at the high end of those for developed countries and double that of the UK. Under these conditions, we use an example to show that over a 60-year period, an Australian park would be judged to return half the benefits of an equivalent UK park. We recommend that long-term investments in green infrastructure that are expected to provide long-term social and environmental returns should use the UK Green Book social discount rates as a base case. There is a case for green infrastructure with few co-benefits that replaces conventional infrastructure to use the higher social discount rates associated with costing conventional infrastructure.

Conclusion

A framework for green infrastructure at the local government scale that aims to build resilience to climate change will need to promote the following attributes:

1. Resilience
    - Green infrastructure needs to be resilient. Because the urban form tends to accentuate climatic extremes, green infrastructure needs to be resilient to extremes of hot and cold, wet and dry, and rapidly changing conditions.
    - By lessening these extremes, GI will provide resilience for the surrounding built infrastructure, reducing damages and wear where possible.
    - GI can confer resilience on the community and business by providing places where people meet and interact, increasing physical and social connectivity, and strengthening community bonds and values.
    - The economic framework itself needs be adaptable in order to manage the different types of projects and contexts in which green infrastructure will be planned and implemented.
2. Risk reduction
    - Climate impact risk reduction contributes to resilience, but is purposely designed to provide specific services that lessen the physical, emotional and financial cost of damaging events.
    - Key risks identified in the urban environment are flash flooding, coastal flooding, drought, extreme heat, and windy and exposed environments. GI can be designed to reduce the impact of all these risks and/or to speed recovery from damage and loss.
3. Liveability
    - Urban environments are not always comfortable places. Grey infrastructure is built to be resistant, and buildings are often constructed with a carefully thought out interior designed for comfort but not so much the exterior. GI can be sued to soften these effects.
    - Improved walkability through provision of shelter.
    - General urban cooling in summer, reduce exposure in winter (if well designed).
    - Services that support individual and community health and wellbeing.
    - Spaces for gatherings, meetings and outings.

Three levels of benefit need to be built into the framework, namely:
1. Individual – benefits that contribute to personal welfare.
2. Community – benefits that accrue to community welfare.
3. Institutional – benefits that fulfil institutional goals and values.

The following principles based on both science and economics will be applied in developing the framework. They are as follows:
- The distribution and allocation of benefits is important. Some benefits a council has direct responsibility for, has a stewardship role in managing or are important downstream and

upstream values in terms of environmental processes. Other benefits may be private or contribute to policies of other government bodies.

- The conservation of mass, function and character is assumed in that economic demand cannot produce goods and services that are unavailable due to physical or institutional restrictions. Irreplaceable aspects of GI need to be identified (within human timelines rather than evolutionary).
- Many ecosystem goods and services produced by GI need to be quantified on a scientific basis to ensure values are adequately represented.
- Monetary values should only be attributed to goods and services that have a market value, have a clear shadow price value or are accepted as standard practice in the area of operation. Further research will be required to develop areas of value that do not meet these criteria.

The conclusions of this green paper will be combined with two other pieces of work: a review of the ecosystem services literature (Symons et al., 2015), the source of the ecosystem services listed in Appendix A and learnings from a set of workshops that explored the decision-making processes surrounding green infrastructure and grey infrastructure in local government (Young et al., 2014a; Young et al., 2014b).

Many of the issues discussed in this paper are difficult to operationalise so where possible, they will have to be simplified to be clear and straightforward to apply. However, for every robust conclusion we can make, other areas will remain ambiguous or continue to be contested within the literature or policy. Where these issues cannot be easily incorporated into the framework, this paper will stand as a record.

Contents

1. Introduction

Background to the project

Cities are complex, dynamic systems that depend on the resilience of their people, economies and natural environments to sustain liveable conditions under ongoing change. Such resilience is strongly influenced by the physical and social infrastructure of a city's location and is a product of its cultural, economic and governance history. Green infrastructure (GI) is increasingly being recognised as a key aspect of the total infrastructure that supports urban liveability, in part by providing resilience to climate extremes (Hamin and Gurran, 2009; Kazmierczak and Carter, 2010; Foster et al., 2011).

Infrastructure is the basic physical and organizational structures and facilities built to service society. Green infrastructure is where nature plays a role in augmenting those services and provides some of its own, such as clean air and water. By absorbing environmental stressors, GI can reduce the impacts of climate extremes such as flooding and heat waves. Communities who successfully maintain these assets are more likely to be resilient and able to adapt more effectively to future shocks and changes (Foster et al., 2011; Lovell and Taylor, 2013). While conventional or grey infrastructure offers protection from some risks, it may exacerbate others. In many cases, green infrastructure can provide multiple positive benefits, often at lower cost as well as reducing some risks (Tzoulas et al., 2007).

In economic terms, liveability roughly equates how a particular place contributes to the social welfare of people and communities. Measures of liveability extend beyond the conventional economy including social and environmental values (Woolcock, 2009; Namazi-Rad et al., 2012; Ruth and Franklin, 2014). Human welfare extends beyond income, because it takes in the quality of life enjoyed by individuals and communities. This comprises the social economy. Liveability also takes in the environment, including the natural environment. Environmental values at the planetary scale encompass global society and the total global economy. These values are attached to the biophysical processes that maintain the global biosphere in a habitable condition. Environmental values are also important in cities (Newman and Jennings, 2012). These values largely contribute to the welfare of the urban community, although a city's environmental services will contribute to broader regional and global processes in a small way.

To date, planning for green infrastructure within Melbourne's local government areas (LGAs) has largely been opportunistic, taking advantage of funding opportunities, rather than being a strategically managed portfolio sustained by ongoing funding (Young et al., 2014b). Green infrastructure is not well integrated with other types of infrastructure, and the tools and methods required to do this are largely undeveloped. Decision makers find it difficult to properly evaluate the type of investment needed, why it is needed and how it is needed. As a result, green infrastructure is viewed as a peripheral aspect of infrastructure planning, so is often underutilised and undervalued. This has meant that opportunities to improve these assets or maximise their benefits have been not been taken up (Young et al., 2014a; Young et al., 2014b).

Supported by funding provided by the Government of Victoria, the Victoria Institute of Strategic Economic Studies at Victoria University is developing an economic framework for green infrastructure in collaboration with four local government bodies: the Cities of Melbourne, Banyule, Kingston and Moonee Valley. The project is led by the City of Melbourne. This framework aims to provide a foundational step in addressing this lack of progress.

The aims of the project are as follows:

> *This project will produce an economic framework to value the benefits of green infrastructure in order to develop the business case for adapting now. As much as is feasible, the project will explore the multiple benefits of green infrastructure in order to develop an understanding of potential returns on investment by adapting urban environments at the local government scale. The ultimate goal of the project is to put investment in green infrastructure at the local government level on a more even footing with investment in grey infrastructure.*

This green paper aims to provide a platform for discussing how these aims may be achieved. It expands and discusses themes introduced in an earlier concept paper compiled for an introductory workshop (Young et al., 2014a) and expanded upon in the workshop report (Young et al., 2014b). The paper also draws from a review of the ecosystem services literature conducted for the project, where a comprehensive list of ecosystem services and valuation tools provided by green infrastructure has been compiled and reviewed (Symons et al., 2015).

Chapter 2 introduces the concept of green infrastructure and contrasts GI with conventional infrastructure, outlining similarities, differences and interactions. Chapter 3 discusses the concept of Total Economic Value (TEV) associated with environmental goods and services. It also discusses the economic underpinnings of urban green infrastructure, especially ecological economics. Chapter 4 addresses a range of economic concepts, and the methods and tools used to apply these concepts. Chapter 5 addresses the current state of play with respect to urban green infrastructure as developed by the project to date. Chapter 6 outlines a proposed framework to be developed to address the aims of the project.

Issues discussed in this green paper, include:

- The place of green infrastructure in broader infrastructure settings
- Applying Total Economic Value (TEV) to ecosystem services
- The relationship between TEV and asset values
- Progress in environmental accounting, especially in Australia
- Exploring intangible and community values
- Discounting and rates of time preference
- Current methods and tools in use
- Broad description of current systems in use at the LGA level including finance, asset management and project systems
- The structure of a potential economic framework

Key concepts

The central economic question guiding this paper is how can multiple values associated with green infrastructure be assessed within an economic framework that can be applied in practice by local government?

The paper does not adopt the orthodox aim of putting a dollar value on everything as a means of prioritising the best decision. Instead it asks how very different values can be applied in practical decision making in a way that accounts for incommensurability between different values. Two values are incommensurable if they cannot be measured using a single metric (e.g., dollars). Simply put, your grandmother is not for sale and nor should she be, nor is your granddaughter's future. No single method will address all the needs required to assess the economic, social and environmental benefits that a GI project or program can produce. A heterodox (beyond the mainstream) approach will apply a range of methods, some of which are non-monetary.

The institutional arrangements for local government project planning and management, and asset management, also need to be incorporated into the final economic framework. Integrating into current practices requires a very pragmatic approach to how economics can be applied.

General approach

A criticism of orthodox economic approaches is that they often overlook community-based values and shared assets (the 'commons') (Hardin, 1968), limiting their assessment to direct profit and loss. This was the primary motivator for developing the concept of total economic value in the 1970s and 1980s (see Chapter 3). Driven by the view that the full costs of any project should be assessed, direct and indirect losses to the environment were assessed to quantify the negative environmental and social impacts of development and balanced projected gains. Later, attention moved to assessing the potential for sustained social and environmental benefits when restoring or rehabilitating green infrastructure. This contributed to the rise of environmental economics and later, ecological economics.

The largest difference between green and grey infrastructure is its complexity and the number of services it can provide. Grey infrastructure has traditionally been single purpose. Roads are for motor vehicles, pipes are for transporting liquids and tracks are for trains. Green infrastructure is, by its nature, multipurpose. Rather than being built for single-use efficiency, it is complex, networked, full of redundancies and structurally complex. This provides the basis for the many benefits it offers, consisting of a limited number of core benefits a range of additional co-benefits. Building on this, conventional infrastructure is now being designed according to ecological principles, applying ecomimicry (Korhonen, 2004).

When applying ecological economics to a project or area, the problem is not too little choice of methods but too much. Assessments can apply a wide range of philosophical, normative and analytic alternatives. Context and framing issues are both very important. Selecting methods that are fit for purpose, especially those that accurately reflect the values they are meant to represent, is difficult. As a result, the literature does not achieve a consensus on how the total economic value of green infrastructure can be assessed, only that it should be.

The task of this green paper is to chart a course between the following considerations:

1. What is the current state of preparedness for assessing the business case for general infrastructure and green infrastructure within a given local government context? This question needs to account for how both green and conventional infrastructure projects are planned, assessed and implemented. The latter issue is addressed in the project workshop report (Young et al., 2014b) and summarised here.

2. Negotiating the assumptions inherent in neoclassical economics and the needs of green infrastructure, accounting for non-monetary or 'intangible' values, social returns and intergenerational equity.
3. Distinguishing between personal, community and institutional values, the latter allocated through regulatory and legal frameworks. This will inform the distribution of benefits.
4. Considering asset valuation from a green infrastructure perspective, especially by accounting for biological growth.
5. Outlining the major links between ecosystem services from green infrastructure assets and adaptation to climate change.

2. What is green infrastructure?

Green infrastructure has no generally agreed definition, however, most definitions have a common theme relating to green and blue spaces in the urban setting. Naumann et al. (2011) provide the following:

> "Green Infrastructure is the network of natural and semi-natural areas, features and green spaces in rural and urban, and terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services. Green Infrastructure can be strengthened through strategic and co-ordinated initiatives that focus on maintaining, restoring, improving and connecting existing areas and features, as well as creating new areas and features." (Naumann et al., 2011, p. 1)

Green infrastructure includes parks and reserves, backyards and gardens, waterways and wetlands, greenery on streets and transport corridors, pathways and greenways, squares and plazas, roof gardens and living walls, sports fields and cemeteries. Note that this definition is different to that in the conventional green growth literature, where it is any infrastructure with a purposefully environmental content (e.g., Hammer et al., 2011).

With reference to the Melbourne region, green infrastructure includes the following:

1. Indigenous flora, fauna and landscape, which may be in various states of health from fairly intact through to almost 100% exotic.
2. Developed open spaces covering parks and gardens including sports fields and golf courses, roadside verges and nature strips.
3. Waste land or unallocated sites where vegetation provides some ecosystem services but is essentially unmanaged.
4. Water-sensitive urban design incorporating natural and artificial components.
5. Vegetation integrated into the built environment, which includes street trees, green roofs and walls.
6. Agricultural and horticultural land, where the primary activity is commercial.

The changing nature of green infrastructure in the Melbourne Region

One important context for any assessment of green infrastructure in the Melbourne Region is to consider its historical context and how that has been influenced by its natural, human and economic history.

Geographically, Melbourne acts as a meeting place for the following five historical aspects.

1. **Geological** – most of the state's major geological formations find their expression in the Melbourne Region. Axes (longstanding tectonic ridges surviving hundreds of millions of years) to the east and west have provided borders for the Port Phillip Sunklands, which provide the peninsulas and bays (Abele, 1988). This provides the context for the regional geomorphology – the landforms on which the city is situated.
2. **Ecological** – most of the state's ecosystems are also represented within the region, even if only in small areas. These range from mallee to montane vegetation. Before European

occupation, the entire region was very strongly influenced by Aboriginal fire management practices, giving the area a classic 'park-like' aspect (Austin, 1974; Presland, 2010). This landscape undoubtedly influenced the early surveyors drawing up plans for the urban landscape.

3. **Climatic** – the Greater Melbourne Region is influenced mainly by westerly weather systems. Its position between the coast and the Great Dividing Range often produces orographic uplift, intensifying weather systems. The boundary between the coast and land, and hills inland can cause rainclouds to rise rapidly, making rainstorms more intense. Its position in the south-east corner of the continent means that blocking highs in the Tasman Sea can produce prolonged heat waves with hot-dry northerly winds coming from inland. South-east lows from eastern Bass Strait can also produce storms and are a major source of Melbourne's water, feeding the Yarra and Thomson catchments. Finally, the circular shape of Port Phillip Bay and the surrounding hills can contribute to the occasional formation of low pressure systems that can circulate bringing prolonged and heavy rains. These diverse influences, contribute to Melbourne's changeable weather (Murphy and Timbal, 2008; Pearce et al., 2011).
4. **Cultural** – histories of the Kulin nations around Melbourne (the Wurundjeri, Bunurong and Wathaurong peoples) suggest that gatherings in the Port Phillip region were commonplace and involved groups from across the state (Presland, 2010). The vegetation at the time of European occupation was greatly influenced by human burning patterns, giving the region its park-like, and to the Europeans, pleasing appearance (Austin, 1974). Economically, the site of Melbourne on the lower Yarra was attractive to Europeans because of the presence of a deep-water harbour, grazing lands, freshwater, timber and good soil.
5. **Economic** – Melbourne achieved its initial wealth from the wool trade, but this was transformed by the discovery of gold in 1851. This led to a boom in wealth and investment that allowed the city to be magnanimous in its planning. Later wealth came through the wool boom, and despite periodic economic crashes, Melbourne has continued to develop and grow. It continues to be the hub for people and goods' feed by a radial transport network. The Port of Melbourne ensures that the region is a hub for trade to and from the remainder of the state.

Geology, soils and climate merge to form biogeographic zones that shape much of a region's natural legacy. The Port Phillip Bay – Westernport and Greater Melbourne Region is a meeting place of some of Victoria's major biogeographic zones. Vegetation communities from the Great Dividing Range and its foothills, the basalt plains, coastal hills and dunes, saline and fresh wetlands, and even mallee vegetation intersect over the area where the city now stands.

These zones are defined by their dominant geology and soils (Society for Growing Australian Plants Maroondah, 1993):

- **Siluro-Devonian sediments** – mallee and box-ironbark forest, dry and wet sclerophyll forests through to rainforest in the upper catchment;
- **Tertiary Sands** – heathy woodlands to heathlands;
- **Basalt Plains** – grassland and grassy woodlands;
- **Coastal Fringe** – coastal heathlands, wetlands and dune vegetation; and
- **Yarra, Maribyrnong and Werribee catchments and delta** – riparian vegetation and wetlands.

Rainfall varies markedly in the Greater Melbourne area; in 50 km from west to east, the rainfall almost doubles, from about 550 mm to over 1,300 mm (and over 2,000 mm in the upper Yarra catchment). Similar sediments occur in the upper and lower Yarra catchment, but the climate, soils and fire regimes are different, grading from grassy woodlands in the drier western sub-catchments to mountain ash forests with fern gullies in the east. Major water-dependent communities fringe the bay, including salt marshes, estuaries and freshwater wetlands.

A radial system of rivers also drain into Port Phillip Bay – the Yarra and Maribyrnong from the east and north, joining close to Hobson's Bay (the Yarra originally flowing into the Maribyrnong) and the Werribee River from the west. A series of smaller creeks also conforms to this radial pattern. Later development of railways and roads has accentuated these patterns.

These systems greatly influenced Melbourne's early settlement patterns. The hills east and west of the Yarra with a pleasing aspect, views of the river and raw materials for housing, became the first settlements and remain the highest value lands within the Melbourne Region. Lower flood-prone lands were turned over to industry and cheap housing, with settlement expanding south and east into the more treed and wetter parts of Melbourne, avoiding the flatter, drier and hotter grassy areas of the west with their inhospitable soils, although areas east of the river were reserved (the botanical gardens and Albert Park) or drained and built on.

A critical part of early Melbourne's planning was the meticulous survey and planning conducted by Russell and Hoddle, which included wide streets and generous parklands fringing the city. Significant boulevards, especially St Kilda Road and Royal Parade were later laid out and incorporated into the development of Melbourne's inner suburbs. The influence of the Colony of Victoria's first governor, Lieutenant-Governor La Trobe cannot be overplayed – he directed the layout of many of Melbourne's parks, preventing their action in land sales and reserving areas for the botanic and zoological gardens and Melbourne University. Turner (1904) writes that when a few hundred acres of Albert and Fawkner parks were later sold off by a colony treasurer, the public outcry was so great it could not happen again.

The park system and water system are the two greatest legacies of green infrastructure at the city-wide scale. Wong (2006) has written extensively on the legacy of Melbourne as a water-based city, identifying six stages of development (Wong 2006; Mekala et al., 2014).

1. A water supply city during the mid to late 1800s, first by securing Yan Yean Reservoir in the 1850s, then moving to the Upper Yarra catchment. The focus was on securing a stable, clean water supply in a variable climate with a rapidly growing population, influenced and financed by the gold rush.
2. A sewered city prompted by public health concerns (mainly typhoid and diphtheria epidemics), developing separate sewerage schemes between the 1880s and 1920s, and opening up the Western Treatment Plant.
3. A drained city with well-established drainage and flood protection systems in the 1920 – 1930s, prompted by a history of large floods in the Yarra River, culminating in a devastating flood in 1934. This saw many waterways straightened and some turned into concrete drains to hasten the passage of stormwater to the sea.
4. A waterway city with a strong emphasis on stormwater pollution management in the 1970s, seeing the first public campaigns to clean up the Yarra.
5. A water cycle city with active promotion of fit-for-purpose water use in the 1990s, with the development of recycling and re-use systems, especially in new developments.
6. A water sensitive city post 2000 with a focus on integrated urban water management.

These developments have been prompted by actions from all levels of civil society. Today, these range from the national Water Reform Process to the activities of local friends groups, and include state and local government and water corporations. A considerable part of Melbourne's legacy as a water-sensitive city is the reservation of Melbourne's upper catchments for water supply in the late 19th and early 20th century. The provision of high-quality drinking water from forested catchments has meant that A-class water has been used for a wide range of purposes when lower water quality water would do. Integrated urban water management is much more focused on developing a fit-for-purpose water supply, making the urban water cycle a crucial part of green infrastructure.

Less well described are the stages of development influencing green infrastructure in the Greater Melbourne Region. These can be summarised under the following themes:

1. Fire stick farming – the extended human history of the Melbourne Region as managed by the peoples of the Kulin Nation shaped the distribution of plants and animals in the landscape, maintaining grasslands in a floristically rich state providing goods such as tubers and seeds and services such as attractive grazing lands (Gott, 1983, 2005; Presland, 2008, 2010).
2. Grazing and clearing – the introduction of sheep saw an immediate change to the region. 20,000 sheep were landed in the first six months and numbers rapidly grew. By 1841, there was a shortage of feed due to the severe drought of 1837–41 and stocking rates (Jones, 1999). Meanwhile around the city, trees and wattles were being cleared for housing and use in tanning (Billot, 1979).
3. Grand parks and gardens – the Hoddle and La Trobe legacy saw the development of a series of large parks and avenues that became embedded into the heritage of Melbourne (Billot, 1979). In the main, this saw the Europeanisation of Melbourne's flora except in areas such as Studley and Royal Parks (Brown-May and Swain, 2005). Science was seen as an important civilising influence so botanical and zoological gardens were established at this stage along with observatories and museums (Griffiths, 1996).
4. Harvesting, growth and development – further development of the urban region, collection of raw materials and drainage of swampy areas continued throughout the 19th and into the 20th century (Presland, 2014). Wild food was a key part of Melbourne's diet (fish, waterfowl, and later, rabbit) and farmland was developed on the better soils in the Melbourne region to feed the growing city. The Heidelberg School of artists encourage a love of the bush, field naturalist clubs thrived and nature studies became a key part of the school curriculum by the early decades of the 20th century. There was generally, however, a clear divide between the bush and the city.
5. Suburbanisation – the period after World War Two saw a long period of expansion beyond what are now the inner suburbs as the city grew south and east during a prolonged period of economic growth. Different waves of immigrants brought their own cultural notions of green infrastructure from Europe and later, Asia (Broome, 1984). Bush was cleared, and farmlands, vegetable gardens and orchards built over, except in designated green wedges, declared in the early 1970s.
6. First wave of native revegetation – the wave of environmental consciousness following the 1960s saw an Australianisation of the landscape, with many Australian as opposed to exotic species planted. However, species were largely imported from other regions of Australia as was the earlier pattern with exotic plants.
7. Indigenous revival – in the 1980s ecological principles were applied in the development of conservation biology and landscape ecology with the development of local provenance principles for revegetation (Trigger et al., 2008). These were formalised with the development of the Natural Heritage Trust, where the use of local native plants was mandated in Landcare

programs. The awareness of the role of indigenous people in the landscape has strengthened over the same time period but overall has received less prominence (de Jong, 2004; Pocock and Jones, 2013).

8. Integrated green infrastructure – the current phase, which is underway in its early stages, is developing a range of strategies that aims to bring together the different traditions involved in urban green space and seeks to integrate these with other forms of infrastructure (Newman and Jennings, 2012). For example, these different traditions include formal gardens, scientific and cultural parks such as botanical gardens, recreational areas, vacant land largely populated by invasive plants, areas with remnant ecosystems and high quality ecosystems in reserves. It is also seeking to combine green infrastructure with other forms, such as rain gardens, green roofs and walls and recreation in high conservation areas.

These stages of the water city and the natural city have affected different parts of the urban region in different ways. Therefore, any given local government area will exhibit its own particular patterns of green infrastructure. However, these patterns can also be grouped, giving a guide to the status of green infrastructure today and how it can be developed in future.

The current state of green infrastructure and how it is seen by a community has many histories – natural, cultural, political and economic. These histories need to be understood in order to blend the heritage element of green infrastructure with its future.

Recommendation 1

The framework needs to support heritage values, including natural and cultural heritage.
It also needs to support long-term time frames and visioning in its use.

Green infrastructure in urban settings

The four city councils involved in the project: Melbourne, Banyule, Kingston and Moonee Valley, occupy the centre, inner north-west, north-east and south-east of Melbourne (Figure 1).

The environments we are dealing with in this project are summarised as follows:

Banyule City: Banyule ranges all the way from the inner suburbs north of the Yarra, to areas that were only developed in the 1970s. Most of the region covers the Siluro-Devonian complex of rolling hills with box iron-bark vegetation, riparian vegetation along the rivers and creeks, and a small area of basalt country to the east. Green infrastructure includes the middle Yarra and its parks and wetlands, Darebin Creek to the west, the lower Plenty River and significant urban box-ironbark and grassy woodlands.

More traditional parkland occurs in the inner suburban areas grading towards peri-urban and riverine parks further afield. Corridors are important as are large reserves to maintain connectivity and habit for people and wilder animals. The city contains extensive suburban areas, as well as significant local and regional flora and fauna. Climate risks that need to be monitored and managed include flooding, heat extremes and fire.

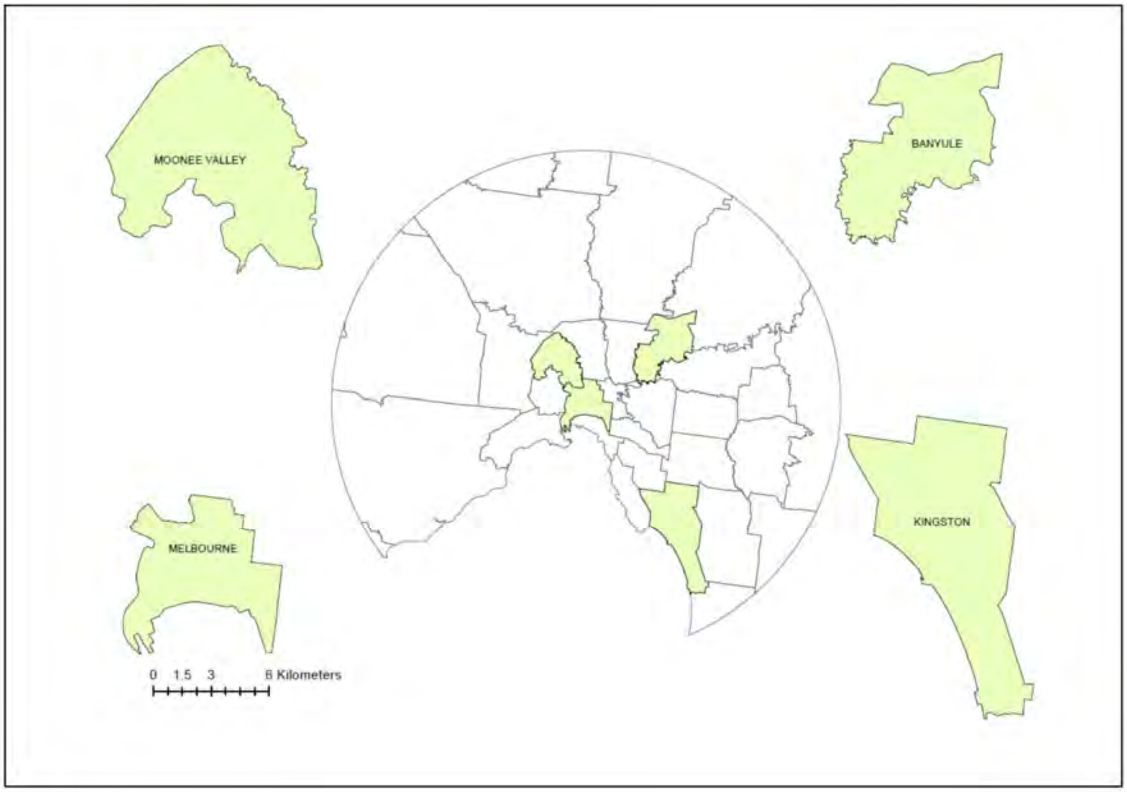

Figure 1. Local government areas involved in the project (source City of Melbourne).

City of Kingston: Kingston takes in the Tertiary Sands Coastal Fringe bioregions of Melbourne, occupying the green wedge in the Keysborough – Carrum zone and part of the former Carrum Carrum Wetlands in the Edithvale Wetlands, an international Ramsar site. It contains several regional parks managed by Parks Victoria and manages a significant length of coastal cliffs, beaches and source-bordering dunes. Mordialloc and Dandenong Creeks are the two most significant water ways.

The city has some older middle suburbs and was formerly a beach holiday location for Melbourne, but has been infilling progressively since WWII. The amount and scale of development has increased significantly around the six Activity Centres in Kingston. In the less developed areas, after years of sand quarrying and landfilling, large parts of the Kingston Green Wedge are finally transitioning out of the waste industry and are proposed to be green parks and/or electricity generation sites such as solar parks. Its main climate-related risks are storm surge and overland flooding.

City of Melbourne: Situated on the Yarra, Melbourne contains all of the biogeographic zones nominated in the previous section except for the coastal fringe. However, very little remains of those except for the underlying geology, as almost all of the original vegetation has been replaced or built over. Limited fauna persists although a recent Bioblitz collected over 3,000 records of plants, animal and fungi that are still being assessed.

However, a significant legacy survives from the grand parks and gardens era, suburbanisation and first wave of natives. The water cycle and water sensitive city has also changed the way that parks and street-side vegetation is being managed. Some vacant spaces with invasive species remain on private and public land. The initial prognosis is that original ecological values are very low, but that scientific and historical values are very high. The recent return of population to inner Melbourne means that the demand and potential use of green infrastructure is rising.

City of Moonee Valley: Moonee Valley takes in part of the catchments of the Moonee Ponds Creek and Maribyrnong River, and is comprised mostly of the basalt plains and Siluro-Devonian bioregions with some riparian vegetation. There are limited remnant ecosystems in the area dominated by grassland, grassy woodland and riparian vegetation, but these total less than 100 hectares. Where reasonably intact, these have a high conservation value.

The inner urban part of the city contains some traditional 19th century parkland, but most of the city's green infrastructure has been highly modified including the Moonee Ponds Creek, which is concrete lined in its lower reaches. Major open space includes Essendon Airport, riverside parks and Flemington Racecourse/Showgrounds. Major climate risks include heat extremes and flooding.

3. Valuing green infrastructure

Green infrastructure emerged as a concept in the 1990s as planners began to consider the organised provision of ecosystem goods and services in the urban context. They noted that urban forests and rivers and streams provide ecosystem goods and services in a similar way to the way that transport and energy systems offer access and power (Teaford, 1987; Walmsley, 1995). This development drew from emerging research themes such as industrial ecology and the city as an ecosystem, but the main inspiration was the development of ecosystem goods and services (Gill et al., 2007; Tzoulas et al., 2007). The term green infrastructure is often used because of its similarity to conventional infrastructure, which is generally seen by federal and state governments as good for the economy and not a drain on resources. However, this is not necessarily the case for local government, who face a significant shortfall between revenue and limited revenue raising powers and demand on infrastructure renewal (Victorian Auditor-General, 2014).

Ecosystem or environmental goods and services are the direct and indirect services provided by any aspect of green infrastructure. These include both use and non-use values (Fromm, 2000). The infrastructure that provides them has been termed natural assets or natural capital. Comprehensive reviews of the history of ecosystem services are provided by Fromm (2000), Fisher et al. (2009), Gómez-Baggethun et al. (2010) and Lele et al. (2013). The valuation of natural assets from the perspective of infrastructure provision is not very well developed, although there is a literature valuing natural assets based on their provision of goods and services (Costanza et al., 1997a; de Groot et al., 2012; Costanza et al., 2014).

The concept of total economic value (TEV) was applied to environmental goods and services during the 1970s and 80s because conventional economic approaches were considered to be partially costing resource projects. The missing values were mostly linked to human welfare from pollution or resource over-utilisation (Mastenbroek and Nijkamp, 1976). Early examples were for pollution (Anderson et al., 1977), fisheries (Randall, 1987) and wildlife (King, 1948), the earliest locatable reference online. TEV became formalised in environmental and ecological economics in the 1990s (Pearce et al., 1989; Tietenberg, 1992), culminating in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2003) and The Economics of the Environment and Biodiversity (TEEB, 2011, 2012).

Three main approaches to green infrastructure have been identified in the literature review undertaken for the project (Symons et al., 2014):

1) **Ecosystem goods and services approach**. This approach emphasises the services that nature and natural cycles provide to society (Ehrlich and Mooney, 1983; Mooney and Ehrlich, 1997; Millennium Ecosystem Assessment, 2003; Costanza et al., 2014). These natural cycles occur over the entire planet (e.g., the carbon cycle), however, they can be restored and maintained within urban settings to provide benefits in that setting.
2) **Green spaces network approach**. This perspective highlights the importance of retaining and linking green spaces and nature corridors in cities to improve the functioning of ecosystems. This perspective mimics traditional infrastructure approaches in that it provides a network for the functioning of a city (Benedict and McMahon, 2002).
3) **Green engineering approach**. This viewpoint considers GI to be a subset of traditional engineering infrastructure whereby typical practices have green elements added to them

which can provide ecosystem services such as cooling through the installation of green roofs and living walls (Margolis and Robinson, 2007).

We will utilise each of these approaches to some degree. For the ecosystem services approach we identify goods and services and attach economic values if they are known. The green spaces approach is used to identify physical assets within a particular area, looking at networks and connectivity. The green engineering approach is used to match 'like with like', where similar functions between different types of infrastructure are contrasted. The latter principle is also applied to asset valuation.

Ecosystem services and total economic value

With respect to TEV, practical and philosophical questions ask whether all ecosystem goods and services can, or should, be given a monetary value. Can all, or only some values be quantified, and can they all be quantified in the same way?

Figure 2 shows the TEV, largely as adopted by TEEB and applied in the European Commission research project Natura (ten Brink et al., 2011) and adapted to increase the importance of health by Young et al. (2014a). It consists of use and non-use values broken down into direct and indirect, options and bequest (quasi-options) and existence values. Their meanings are briefly described in Table 1.

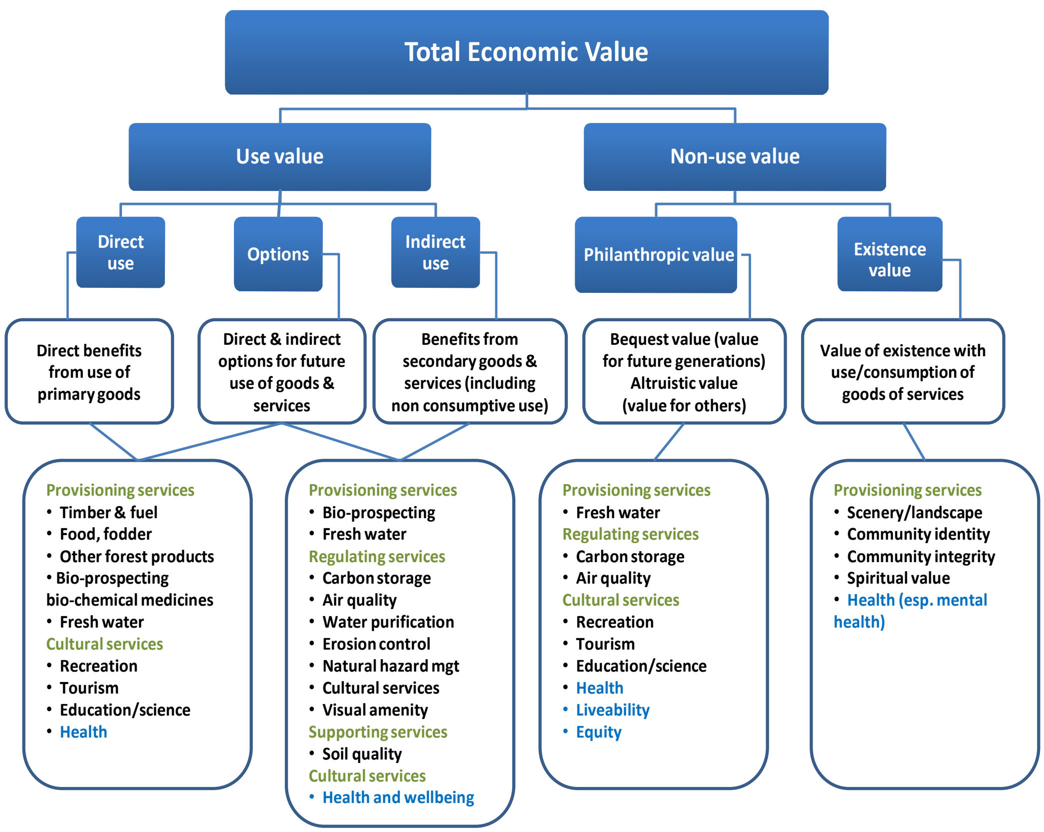

Figure 2. Total Economic Value system with health and wellbeing additions – adapted from ten Brink et al. (2011) and Young et al. (2014a).

Sometimes use and non-use values are described as intrinsic and instrumental values. Intrinsic values are a long-standing philosophical notion that lies at the heart of ethics, where things are valued for their own sake or own right (Zimmerman, 2010). This has been transferred to the idea of intrinsic values in nature, where nature is valued in its own right independently of the direct benefits it may provide to people (Eckersley, 1992; Callicott, 1995). Note that these definitions differ from the idea of intrinsic value in economics and finance, which is the expected future value of a stock, good or production unit (e.g., Lee et al., 1999). Total economic value is a very useful concept for tallying up all the potential benefits of a project or precinct.

Table 1. Meanings of the word 'value' as used in ecological economics. Adapted from Callicott (1984), Gilpin (2000) and Kumar and Kumar (2008).

Type of value	Meaning
Economic value	The worth of a good or service, or the measure of benefit provided by that good or service. Economic value is not just monetary, and there are many definitions across different economic traditions, from financial to philosophical.
Market value	The exchange value or price of a commodity or service in the open market. Sometimes also synonymous with **economic value** in neoclassical economics.
Use value	The equivalent value of a good or service that is not paid or partially paid for, translated into market-equivalent value.
Intrinsic value	The value attached to the environment and life forms for their own sake irrespective of any reference to humans.
Existence value	The value attached to the knowledge that species, natural environments and other ecosystem services exist, even if the individual does not contemplate ever making active use of them.
Bequest/vicarious values	A willingness to pay to preserve the environment for the benefit of other people, intra- and inter-generationally.
Present value	The value today of a future asset, discounted to present day values (e.g., today's dollar value).
Option value	A willingness to pay a certain sum today for the future use of an asset.
Quasi-option value	The value of preserving options for future use assuming an expectation of increasing knowledge about the functioning of the natural environment.
Anthropocentric value	Confers intrinsic value on humans alone and instrumental values on everything else.
Non-anthropocentric value	Intrinsic value is attributed to human and non-human beings, and perhaps natural systems.
Tangible value	The monetary or market values of a good, service or asset.
Intangible value	Non-monetary goods, services, assets and intrinsic values.
Community value	A value shared by or benefiting a group of people who constitute a community through place, activity, or shared aspirations and goals.
Institutional value	Value held by an institution as a guiding principle and/or goal.

One aspect where use and non-use values do not map easily onto intrinsic and instrumental values is with the notion of acquired or inherited value, where the 'goodness', rarity, desirability or fame of an object provides it with values greater than like objects. For example, a heritage-listed tree is more valuable than a common street tree. Acquired value is a difficult concept to map across the divide between intrinsic and instrumental values, because intrinsic value suggests that all species should be equal, but we spend much more time conserving cute photogenic species and iconic sites of natural beauty. This has given rise to the Ugly Animal Preservation Society, who exercise the intrinsic value of species' existence through reverse psychology by celebrating ugly animals deemed worthy of conserving (O'Callaghan, 2013).

In urban environments, acquired values have a historical and cultural context that changes over time, affecting the urban aesthetic (Head and Muir, 2006). Acquired values are present in areas such as the Fitzroy Gardens, the Botanical Gardens and the Domain in Melbourne, Alexandra Park in Moonee Valley, parks along the Middle Yarra and the Heidelberg School landscapes in Banyule. In Kingston, the Carrum Carrum Wetlands were of great value to the Bunurong people (Presland, 2014), but lost favour with the Europeans and then were subsequently modified and drained. They have only recently re-acquired their heritage values in the much diminished Edithvale-Seaford Wetlands which, following their Ramsar listing in 2001, now have international heritage values. Changing attitudes to the intrinsic values of biodiversity, promoted particularly through conservation biology, natural heritage and sense of place also indicates that the intrinsic values of nature – the right to a species or ecosystem's existence – have changed over time, so are culturally directed (Griffiths, 1996; Head and Muir, 2006).

Key differences between intrinsic and instrumental values include:

- intrinsic values are more likely to be shared community or cultural values,
- they have a different philosophical basis not based on individual utility (see Glossary), requiring a different style of valuation (Sagoff, 1998; Spash, 2008) and
- exhibit different psychological dimensions (Kumar and Kumar, 2008).

However, all societies have rules and regulations that administer intrinsic values, both explicitly and implicitly. These form institutional values that are not traded in markets, although society will invest in them to a greater or lesser degree. With regard to green infrastructure, such values may concern things such as biodiversity, spirituality or community heritage.

ten Brink et al. (2011) discuss intrinsic value with respect to TEV, but their Figure 2 above contains largely instrumental values; intrinsic value is identified but is generally not given a monetary value. We intend to follow that broad model (which has been used by a great many projects) and restrict the monetary part of the framework to instrumental values. This may include some acquired values, for example those that value parts of the urban landscape more than others, and where a 'price' can be estimated. Intrinsic values, particularly those held by communities, are very important but require different methods of valuation, as discussed later in the paper.

The concept of TEV has been used very successfully in environmental accounting to assess the value of many assets and monitor change in asset value over time, but it tends to work best for those values that can be quantified more easily (Metzger et al., 2008; Busch et al., 2012). Accounting is able to identify and quantify the physical stocks and flows of goods and services, but economics is required to quantify values for those assets, goods and services. Issues with valuation that limit its economic effectiveness include limitations in calculating exchange values for complex and open functions, assessing 'goods' and 'bads', aggregation of multiple services and site specificity (Hein et al., 2015).

The most straightforward valuation relating to GI is for ecosystem goods and services traded within markets. However, current accounts show that the contribution of biodiversity-related income is tiny, and of green infrastructure generally is small, emphasising the need for a more comprehensive approach (Jones and Webb, 2008). Welfare economics is the other major area of activity (Hein et al., 2015), but valuing intangibles remains problematic. The difficulty with converting intrinsic values into dollars, in distinguishing intrinsic and acquired values from each other, and the potential for double-counting the goods and services that GI provides, suggests that total economic value cannot be calculated meaningfully (Spash, 2008). Given these limitations, calculating comprehensive economic value as suggested by Opschoor (2004), where a number of different measures are used, but the assessment remains comprehensive, is a much more suitable goal.

Total Economic Value (TEV) is a useful concept for accounting for the many goods and services provided by green infrastructure, but its very different component values (from market to spiritual and ethical) mean that adding them using a single metric (e.g., dollars) to find 'total value' is not feasible.

Recommendation 2

The economic framework should pursue a concept of comprehensive economic value as the most appropriate term for valuing ecosystem goods and services, using a variety of economic approaches. The total economic value framework in Figure 2 can be used to identify the different benefits provided by GI. These would then be assessed using an economic framework capable of calculating different value types.

Summary of ecosystem goods and services

Ecosystem goods and services can be divided into social, economic and environmental groups in line with the familiar triple bottom line approach.

Social benefits

Social benefits are diverse and often hard to measure and many, such as community identity, amenity and equity, are indirect. Health benefits include mental, physical and spiritual health (see Figure 3). The provision of clean air and water and places to walk and exercise provide the basis for improved community health. Green infrastructure can also play a role in connecting communities through social activities in public spaces.

Economic benefits

Green infrastructure contributes to the economy via the direct supply of goods and services. The indirect benefits to the economy are many, but hard to quantify. By improving amenity, GI can also increase property values and improve consumer activity in some precincts (Pitman and Ely, 2014). Ecosystem services also provide a 'free service' that can support other economic activities such as recreation, sport and tourism. In some cases, it may provide the basis for such activities (e.g., ecotourism, extreme sports).

Environmental benefits

Environmental benefits contribute directly to environmental protection or to improvements in environmental health that may contribute to social and or/economic benefits. Direct benefits include healthy ecosystems, healthy populations of flora and fauna, connectivity of different spaces and structure that promotes and protects species diversity. The ecological resilience created in healthy ecosystems also supports the overall resilience of a place to environmental extremes.

Box 1 outlines three levels of green infrastructure, the benefits of which are detailed in Appendix 1. This list is collated from Bolund and Hunhammar (1999), Mainka et al. (2008) and Pataki and Carreiro (2011), and will be added to over time.

Box 1. Major social, economic and environment benefits of green infrastructure

1) Social
    i) Human health and wellbeing
        (a) Physical
        (b) Social and psychological
        (c) Community
    ii) Cultural and spiritual
    iii) Visual and aesthetic
2) Economic
    i) Commercial vitality
    ii) Increased property values
    iii) Value of ecosystem services
3) Environmental
    i) Climate modification
        (a) Temperature modification by reducing extremes and raising or lowering air temperature
        (b) Shading
        (c) Evapotranspirative cooling
        (d) Wind speed modification
    ii) Climate change mitigation
        (a) Carbon sequestration and storage
        (b) Avoided emissions (reduced energy use)
    iii) Air quality improvement
        (a) Pollutant removal
        (b) Avoided emissions
    iv) Water cycle modification
        (a) Flow control and flood reduction
        (b) Canopy interception
        (c) Soil infiltration and storage
        (d) Water quality improvement
    v) Soil improvements
        (a) Soil stabilization
        (b) Increased permeability
        (c) Waste decomposition and nutrient cycling
    vi) Biodiversity
        (a) Species diversity and population viability
        (b) Habitat and corridors
    vii) Food production
        (a) Productive agricultural land
        (b) Urban agriculture

When assessing values, it is important to identify the final benefit in a value network or chain (both are possible). Although all benefits should be recognised, adding up intermediary benefits may lead to double counting. On the other hand, a single service may lead to multiple benefits or satisfy more than one area of value, so is why connections between different benefits need to be kept visible in any assessment.

For example, an urban wetland can provide flood control (risk reduction), cooling, visual amenity, aquatic fauna and flora habitat, urban conservation services, nutrient stripping and recycling and educational services. At the individual scale, people enjoy additional wellbeing, recreation and visual amenity as social services. At the community scale, it may be a place of shared values, act as a meeting place and have a friends' group, which adds value to the wetland and to the community. A hotel with a view over the wetland will be able to charge higher prices if the view is attractive enough and adjacent dwellings will have a higher value, are examples of potential economic benefits.

Environmental accounts and urban green infrastructure

As per Recommendation 2, TEV is most useful as an accounting system, rather than as an economic system. In that sense, TEV is a tool to ensure that all values are represented, rather than being an economic framework in itself. Accounting is not simply a tool to monitor or audit resource use. Systemic approaches to accounting aim to have a human system learn about itself in order to track its performance in reference to where it wants to go (Boyce, 2000; Milne et al., 2011).

With reference to environmental accounts, the United Nations System of Environmental-Economic Accounting (SEEA) is the first international standard for environmental-economic accounting (United Nations, 2014) and is supported by an associated ecological methodology, which is currently being finalised (United Nations, 2013). This process is also being pursued in Australia (ABS, 2012), with the first national environmental accounts being released recently (ABS, 2014). Further information on these initiatives is published under the National Plan for Environmental Information (Bureau of Meteorology, 2013a, b).

Four main types of accounting in the SEEA framework are added to the existing monetary stock and flow accounts of the System of National Accounting:

1. Physical flow accounts record flows of natural inputs from the environment to the economy, flows of products within the economy, and flows of residuals generated by the economy (including water and energy used in production and waste flows to the environment).
2. Asset accounts in physical and monetary terms measure the natural resources available and changes in the amount available.
3. Functional accounts for environmental transactions record the many transactions between different economic units (i.e., industries, households, governments) that concern the environment.
4. Ecosystem accounts are structured to summarise information about complex plant, animal and micro-organism communities, their non-living environment interacting as a functional unit and their changing capacity to operate as a functional unit and their delivery of benefits to humanity.

The first three types account for flows, stocks and transactions, and the fourth takes in ecological accounts, which are at present experimental. They closely follow the TEV structure detailed in the previous section. The European Environment Agency is proposing the Common International Classification for Ecosystem Services (CICES) for final ecosystem goods and services, through the three major groupings of provisioning, regulation and maintenance, and cultural services (Haines-Young and Potschin, 2012). However, this framework is largely based on the side of supply and does not take the perspective of the beneficiary.

A number of frameworks and projects in Australia and overseas are summarised by the Bureau of Meteorology (2013b), but none are really suited to urban situations. This is because they are focused on broad-scale ecosystem services and resource conservation in rural regions, aiming to increase sustainability at the landscape scale. For example in a recent review of Australia's ecosystem services applications, the only case study relating to urban areas, was the historical mention of Melbourne's closed water catchments (Pittock et al., 2012). This is partly a research bias, but also shows the separation between urban and non-urban ecological research. Environmental accounting in urban areas requires a fine-scaled approach relevant to the scale of service delivery and infrastructure providing it. This indicates that building environmental accounting into existing project and service delivery in local government that do work at those scales, is a better approach than developing a separate set of accounts.

Also, because people are the main beneficiaries there is a greater emphasis on social, rather than environmental, values. Consequently, the role of green infrastructure in sustaining human health and wellbeing is under-emphasised in existing applications. Although there are existing wellbeing indices, such as the Hale Index of Australia's Wellbeing (Lancy and Gruen, 2013; Waksberg and Gruen, 2013) and the genuine progress indicator (GPI), these are too coarse for urban use. For example, in the Hale Index, the environment is given one number, relating to gradual climate change. Jones (2010) describes an accounting framework designed to practice sustainability and report performance, but most existing schemes are aimed towards ensuring ecological sustainability at the landscape scale, which would be relevant to cities but remains theoretical, having not yet widely been put into practice.

Environmental accounting systems are in their early stages of development and are currently not that well suited to application at the local government scale.

Recommendation 3

The economic framework needs to apply accounting for environmental assets and services, building on existing systems within local government where possible. Current recording and monitoring systems within local government are being investigated as a result. The operation of environmental accounts ideally should yield net benefits and not use up resources with little promise of return. This can be done within an innovation and systems-driven approach, but it needs to be straightforward to apply.

Economic evaluation methods – a brief history

The different values outlined in Figure 2 and Table 1 are used in a variety of different decision contexts, requiring a plurality of methods (Spash, 2008; Laurans and Mermet, 2014). Ecological economics, which is the major influence on the valuation of green infrastructure, is a fertile area of investigation but lacks a clear consensus on how its findings should be applied.

Approaches range from models of the physical economy through to market-based models designed to allocate specific resources or processes. Table 2 lists a variety of types of economy and economic traditions contributing to ecological economics. Gómez-Baggethun et al. (2010) describe a useful history of ecosystem services in economic theory and practice that traces an informative path through the various traditions, placing them within historical context.

The emphasis of classical economics on land capital implied a strong link to natural resources, which underpinned agricultural productivity. This gave rise to the Malthusian limits of population, food and land where it was feared these natural limits would prevent further growth. However, the transition from rural to urban economies and from agricultural production to manufacturing and services, postponed meeting these limits. This led to the conclusion that the transfer between land to labour and manufactured capital was frictionless and that the two capitals were perfectly substitutable. With neoclassical economics moving into the realm of manufactured capital, the transition to the production and consumption of goods and services and the assumption that this maximised utility for the individual, became the driving force for economic theory. This altered the focus on economics from assessing capital value to marginal value. The working assumptions of neoclassical economics are:

1. People have rational preferences between outcomes that can be identified and associated with monetary values.
2. Individuals maximize utility and firms maximize profits.
3. People act independently on the basis of full and relevant information.

The downside of industrialisation was being felt through a loss to human health and welfare via soil, water and air pollution. The depletion of natural resources was also recognised as a key concern. This led to the concept of externalities and social costs (Coase, 1960). These were firstly addressed by government taxes and then by property rights that limited the right to pollute/deplete. The first generation of environmental economics that built onto these developments therefore was consistent with neoclassical economics. The limits explored by the Club of Rome (Meadows and Club of Rome, 1972) are more sophisticated than those of Malthus, and current rates of resource depletion are tracking the scenarios constructed in the early 1970s (Turner, 2008).

The maturation of the science of ecology, combined with philosophical and mystical traditions valuing nature, led to the birth of ecological economics. The significant difference between environmental and ecological economics is where nature is placed. For environmental economics, relationships between the economy and nature are mainly economic. Ecological economics places the economy as being nested within the global environment with limited exchange between the economy and nature.

Table 2. Types of economy and economic traditions contributing to ecological economics.

Type	Description
Monetary economy	The part of the economy where goods and services are traded for money, and assets are sold in the marketplace. The market/non-market economy is delineated according to barter and trade.
Non-monetary economy	The part of the economy where goods and services are provided without monetary exchange (e.g., household labour, volunteerism, ecosystem services). Assets are generally (though not always) publicly owned.
Physical economy	Stocks and flows in the material world, often simulated using input-output tables of material flows (Lenzen, 2006; Vardon et al., 2007; Turner, 2008).
Environmental economics	Assesses the impact of environmental policies and the role of the environment in the economy, especially where market failure leads to environmental degradation. Sees the natural environment in exchange with the conventional economy to maximise human welfare and focuses on marginal costs and benefits as opposed to absolute values.
Ecological economics	Assesses ecosystems goods and services for their contribution to human welfare and in their own right. Treats the economy as being nested within the global environment with limited exchange between the two.
Weak sustainability	Assumes substitutability between natural and manufactured capital and that environmental degradation can be compensated by payments from the monetary economy (Rennings and Wiggering, 1997; Ayres et al., 2001).
Strong sustainability	Assumes that many aspects of natural capital and the services it provides cannot be substituted or compensated by money, and that natural and manufactured capital are complementary (Gowdy and O'Hara, 1997; Rennings and Wiggering, 1997; Ayres et al., 2001).
Classical economics	Economic theory based on the supply of capital (land, labour) as the means of production.
Neoclassical economics	Economic theory based on rational choice of the individual based on price, supply and demand. While classical economics was based on capital value, neoclassical economics has been based on marginal value and the maximisation of utility. This has been expanded in recent decades to take in social values as welfare economics (Gómez-Baggethun et al., 2010).
Deep ecology	First coined by Naess in 1974, deep ecology is a philosophical position that attributes intrinsic value to the natural world, places humans within this and suggests humans have no right to exploit this for more than basic needs (Naess, 1986).
Polycentric economic approach	Economic methods and approaches to a multi-layered system where “many elements are capable of making mutual adjustments for ordering their relationships with one another within a general system of rules where each element acts independently of other elements” (Ostrom, 1999).
Heterodox economic approach	Application of economic methods without recourse to one particular orthodox position.

Starting assumptions between the two approaches are different. The base assumption in environmental economics is that there is an opportunity cost if natural areas are left undeveloped. For example, surplus undeveloped public land will be valued at the highest commercial market price.

To be maintained in its natural state, the environmental returns of that land need to exceed the financial return from sale and/or development. This is generally the case unless zoning or other considerations prevent the land from being commercially developed. The only such limits for private land are clearing controls, zoning for flood and fire hazards, or areas of designated heritage value. This places natural areas with low utility in dollars, limited acquired value by the community but high conservation status, such as native grasslands, at a disadvantage.

Under ecological economics, economic and ecological benefits are not considered to be readily interchangeable. Ecological valuation will also consider an opportunity cost if ecosystems services are removed by development. In the example above, an ecologically-weighted assessment would value the land at the price it would be sold for with the ecosystem intact, because the land could not be developed due to its conservation status. The basic principle is that if economic, environmental and social benefits are all considered to be of value to society, then these values would be more evenly weighted.

'Deep ecology' principles gives the greatest weight to ecological values. Here, the case has to be made that the conversion meets basic human needs and outweighs natural values (Naess, 1986).

Ecological economics depends on science to locate ecological limits, and identify and measure key functions underpinning the supply of ecosystem goods and services and ecosystem health. These differences, between the norms used to define baselines and 'good' development and in the use of science versus economics to weight trade-offs, have been used to delineate strong and weak sustainability but, in reality, there many gradational aspects between the two.

Two areas of controversy within the literature discussed by Gómez-Baggethun et al. (2010) are:

- the level of substitutability between ecological and economic supplies of goods and services; and
- the allocation of values within an economic framework.

These are major contributors to the "strong" versus "weak" sustainability debate (Toman, 1999). Weak sustainability assumes high substitutability and will allocate dollars to a wide range of values. Strong sustainability will have strict limits on substitutability and ecological limits, and treat some values as being different and incommensurate (i.e., one cannot be expressed in terms of the other).

There is significant support within ecological economics for applying scientific principles, such as the conservation of mass, species and ecosystems to inform trade-offs and physical limits, because the implicit assumption of substitutability in conventional economics fails to account for the depletion of non-substitutable natural resources (Christensen, 1989; Costanza et al., 1997b; Norton and Toman, 1997). On the other hand, the scientific framing of limits and trade-offs is also being critiqued as bypassing important economic considerations (Sagoff, 2008; Gómez-Baggethun and Ruiz-Pérez, 2011; Sagoff, 2011). An approach where they inform each other is preferred.

To date, environmental and ecological economics have mainly focused on changes in marginal cost, pricing environmental goods and services using conventional and expanded cost-benefit approaches (OECD, 2006). The basic cost-benefit approach of orthodox economics prices ecosystem goods and services into a single monetary metric. Expanded methods assessing a greater range of tangible and intangible values, where dollar values are estimated for social services such as human health and wellbeing and environmental services such as biodiversity and conservation. This is now widely recognised as being too limited an approach because of the risk of commodifying aspects of nature that should not be commodified (Norton and Noonan, 2007; Gómez-Baggethun and Ruiz-Pérez, 2011; Turnhout et al., 2013). The next section discusses the issues involved in moving beyond the expanded cost-benefit approach.

Values associated in the economy, in nature and held by society are not readily interchangeable within a neoclassical economic framework.

Recommendation 4

A framework for valuing green infrastructure requires the integration of science, economics and social policy to ensure the efficient and appropriate transfer of values between the environment, society and the economy. To be implementable by local government, this needs to consider existing structures and future needs by taking into account current practices and how they are likely to evolve over time. Important information about values and benefits is also being obtained from local government and other key stakeholders on an ongoing basis so also needs to be considered.

Current status and potential approaches to valuing GI benefits

Ongoing debates within ecological economics regarding how various values should be represented economically, are also occurring within mainstream economics (Norton and Noonan, 2007). Economic measures under consideration range from market prices and prices calculated using economic models, through to values calculated using various proxy methods and those established on ethical or legal grounds.

The complex nature of green infrastructure contributes to a broad array of goods and services with very different values and beneficiaries. The scientific and economic considerations for assessing value and the different decision-making contexts these values will be applied within, point to the need to take a polycentric and heterodox economic approach (Lebel et al., 2006; Söderbaum, 2008; Ostrom and Cox, 2010). This can be defined as the economic methods and approaches to a multi-layered system where many elements are capable of making mutual adjustments for ordering their relationships with one another within a general system of rules where each element acts independently of other elements (Ostrom, 1999; Ostrom, 2009). This approach has also been recommended for climate change, another complex, multi-dimensional issue (Kwadijk et al., 2010; Ostrom, 2010, 2012).

This section discusses the strengths and weaknesses in different types of valuation methods and outlines how they may be used to value the benefits of green infrastructure.

Economic assessments are commonly assumed as being value neutral but the underlying assumptions behind different methods (utilitarian, needs-based, distributive) are all positivist in some way (i.e., good things will happen if the results are acted upon) (Norton and Noonan, 2007). For example, cost-benefit analysis (CBA) is widely used in policy-making because it can be used to compare different projects using a common metric. CBA is presented as an objective, comparable evidence-based approach which is insulated from subjective valuation methods (Sagoff, 2007). For these reasons, it is generally preferred to methods such as multi-criteria analysis, which are project-specific in terms of the criteria used and how they are ordered (Dobes and Bennett, 2009). The weak counter argument to this is that political and policy decisions apply subjective values in any case. The strong counter argument is that many of the values being combined in expanded cost-benefit analysis are incommensurate or are omitted for being incommensurate (e.g., Norton and Noonan, 2007; Spash, 2008).

A complementary method for valuing social benefits is to use a welfare-based approach. Welfare can be measured using metrics that range from direct economic benefit (e.g., reduced health costs, increased productivity) and dollar-equivalent benefit to wellbeing, to a rights-based approach that provides essential needs (both material and non-material) (Lawn, 2003). The two main approaches are utilitarian, where benefits to an individual or community are transferrable and the aim is to optimise beneficial outcomes across the widest range of people; and ethics-based, where the right action is preferred over the wrong action (Sagoff, 2011). These actions can take the form of laws and regulations or policy based on cultural norms.

Two controversial aspects of valuation are understanding where individual and community values intersect and the monetisation of intrinsic value. It is widely accepted in the sociological and philosophical literature that individual and community values have different characteristics to the point where they are not readily exchangeable (Coleman, 1988; Putnam, 1993; Durkheim and Lukes, 2014). Community values do not reflect the collective expression of individual preferences but address the relationships and interactions between people and groups.

The two main aspects of community values are social cohesion and social capital (Kawachi and Berkman, 2000). In defining the sense of community influencing cohesion, McMillan and Chavis (1986) suggest membership, influence, integration and fulfilment of needs and shared emotional connection. In his initial definition of social capital, Coleman (1988) proposed: obligations, expectations, and trustworthiness of structures; information channels; and norms and effective sanctions. In terms of structure, he offered network closure and accessible social organization. He also identified important social networks within and outside the family and the public goods aspects of social capital. Social capital is built from social cohesion and continually needs to be renewed to ensure that capital is maintained. Gsottbauer and van den Bergh (2011) also discuss individual values such as altruism, fairness and reciprocity, which relate individual preferences within groups.

Together, these form the basis of civil society, whose role in the generation of wealth (broadly interpreted) will be overlooked if individual utility is the only thing being considered. For example, the communal republics of Florence, Bologna and Genoa did not become civic simply because they were rich: they became rich because they were civic (Putnam, 1993). A task for this project is to understand how green infrastructure can contribute to community values and these values can be used to support green infrastructure.

A further consideration for collective values is at the institutional level, where the community can be considered as one (but vital) member. Institutions are rules and norms held in common by social actors that guide, constrain, and shape human interaction (North, 1990). Institutions can be formal, such as laws and policies, or informal, such as norms and conventions (Jones et al., 2014). Organizations, such as city councils, develop and act in response to institutional frameworks and the incentives they frame (Young et al., 2008), in this case through governments and Government Acts, state and local. Councils also have ongoing relationships with their communities that influence their actions as managers of key community assets.

Institutions, including local government, the community, state government, industry groups or collectives all have values they aspire to (stated values, often in policy) or exhibit (revealed values, how they behave). Institutions, a key part of civil society, are charged with managing many of the intangibles associated with social and environmental values listed in Figure 2. Methods developed by Ostrom (2005, 2007b, a, 2011) are being used to assess a broad range of community and environmental values within institutional frameworks; some of these are discussed in the next chapter.

Intrinsic value can be estimated using individual willingness to pay (WTP) or willingness to accept an abandonment or loss (WTA). However, because intrinsic values are shared communally and culturally, a wide range of opinion asserts these cannot produce reliable calculations (Spash, 2008; Spangenberg and Settele, 2010). Individuals may be asked how much they would pay, or prefer their taxes to pay to preserve a significant natural asset, but there is no market, and these values are shared widely (though not universally) across the community in any case. So it is a shared value, and best asked of the community.

Some of the largest criticisms of individuals' WTP and WTA 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.

Evidence testing of loss and gain preference for ecological value is less clear cut (Murphy et al., 2005). It depends on whether a good or service is dealt with in a market-like way and what its level of substitutability is considered to be (Mitchell and Carson, 1989). This amplifies the bias to loss for non-tradeable and non-substitutable goods and services (Hanemann, 1991). Further issues exist with stated (from survey) and revealed (what people pay) methods – while they may work in market-like situations, they cannot readily be extended to public goods, where the gain/loss bias increases up to 3:1 (Loomis, 2011). The relative distances within an assessment involving WTA and WTP or stated and revealed preferences are generally reliable if the choice is tightly controlled and addresses a real transaction, but does not work if an open-ended choice is given (Hanemann, 1991). Gsottbauer and van den Bergh (2011) provide 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.

Two methods for managing intrinsic values are simple ranking schemes (Bengston, 1994) and deliberative monetary valuation (Niemeyer and Spash, 2001; Spash, 2007; Lo and Spash, 2013). Recent citizen juries and exercises in limited democracy carried out at the local government level, help community representatives to make informed decisions about their priorities, have combined community and intrinsic values to identify shared values and set priorities for investment (e.g., Melbourne City Council and Mornington Shire Council).

To summarise the various approaches discussed here:

- At the individual level, expanded cost-benefit analysis can be used to assess benefits in market and market-like situations. This will include WTP and WTA methods if used with care.

- At the community level, community and intrinsic values are best assessed using deliberative democracy-type approaches, rather than adapting methods suited to market analysis.
- At the institutional level, rules direct local government and set the framework for how valuation is carried out and applied.

A polycentric approach (focusing on multiple scales; Table 2) will account for all of these approaches, although this is easier said than done. In the next chapter, how key economic issues may affect framework development are discussed.

Recommendation 5

A polycentric framework is required to address three levels of value:

1. Individual values – values that can be allocated to individual benefit.
2. Community values – values that the community share based on community relationships and interactions.
3. Institutional values – stated or realised values held within an institutional context that can be related to a specific target or level of benefit.

The framework should be constructed to allow these three different elements to order their relationships with one another within a general system of rules where each element acts independently of the others. It also needs to be applied while maintaining high useability, so the placement of each level in the framework needs to be quite clear to the user.

4. Economic considerations

Scientific vs economic models

As outlined in the last chapter, a major issue in valuing GI is reconciling scientific and economic approaches to valuation. There is no single approach that integrates green infrastructure with economic activity (Wegner and Pascual, 2011). Scientific models represent ecosystem processes much better than economic models but have their limitations when it comes to representing economics.

Scientific approaches use models that simulate the behaviour of the project or system in question, adding costs and benefits. For example, for stormwater modelling systems, models assess the cost and performance of water sensitive urban design elements, then use a set of established costs and benefits to rate its performance. These are essentially scientific or engineering models with added production functions (Wainger and Mazzotta, 2011). Another type of modelling system consists of spatially explicit (landscape) models of natural assets and supply of ecosystem services, which can be based on agricultural, hydrological, forest production and general land-use models. Values can be attached to these to estimate output (Nelson et al., 2009; Kragt et al., 2011).

Intangible values can be added to physical models, but because many projects require these values to be monetized for cost-benefit purposes, this can be limiting. However, it is possible to produce output in other units; e.g., illness or mortality avoided due to intercepted pollutants and so on, and provide benefits using several metrics. The major limitation of scientific models is that they can assess the primary economic benefits of GI, but cannot assess the flow-on effects of these benefits within the broader economy. Nor can they address supply and demand particularly well.

However, economic models, such as computable general equilibrium models that can do this, are limited in their representation of physical stocks and flows, based as they are on the principle of a single rational agent (or household) to represent decision making in the economy. They do not represent irreversible ecological processes, thresholds, local diversity, non-substitutability or multiple preferences for values that show diversity over time and space, hence the preference for a single fungible metric, like money. They can be used to represent imperfect substitutability by changing the elasticity between different transactions and can be adapted to simulate some of the dynamics listed above, but only crudely.

More dynamic methods are under development but remain experimental. Projects that have combined both aspects are the contribution of ecosystem services to the economy around Davos Switzerland using input-output tables to assess sectoral benefits (Grêt-Regamey and Kytzia, 2007), scaling up of green roof projects in Washington DC to assess city-wide benefits (Niu et al., 2010) and urban economic models of land-use change (Irwin, 2010).

Available models with local data and local context are limited to water infrastructure and street tree models. There are as yet no economic models for GI available for greater Melbourne, or those that are capable of calculating a widespread range of benefits from GI that are representative of a local government area. Individual research projects have assessed pollution, heat stress, energy benefits and flood mitigation, but these have not yet been scaled up.

Aggregating the collective values of GI

One difference between private and public goods is that the value of private goods can be gauged by the price an individual will pay within a market, whereas for public goods the consumer or user of that good does not have to convey what that good is worth to them (Bradford and Hildebrandt, 1977). Aggregated value for private goods can be gauged by supply, demand and price. Aggregate value for public goods is much more difficult to determine.

Goods and services are exclusive if they are personal and consumptive and non-exclusive if shared and non-consumptive. For example, an apple is an exclusive good because it can be consumed by one person, whereas air and views are non-exclusive because they are not consumed but are shared. All four combinations of public/private and consumptive/non-consumptive are possible. Many of the goods and services provided by GI are non-exclusive, but may be limited in the sense that only a certain number of people can enjoy them before they become over-exploited.

The most important aspect of public goods is often their quality rather than quantity. For example, access to a basic amount of open space is generally mandated within planning schemes and is mostly, but not always met. However, the greatest open space value lies not in its supply but in its quality as an asset. For example, high quality parkland provides a much greater level of services, has higher visitation rates and contributes both public and private benefits in the form of higher surrounding property prices, than does a paddock with a bit of grass.

Aggregate demand for social benefits can be allocated to individuals and to the community depending on context. Conventional economic approaches will aggregate individual values to obtain total value and apply that to cost-benefit techniques (Mitchell and Carson, 1989). Collective values are seen as quite different. Community values are based on relationships that include trust, reciprocity and shared values and, as such, are different to aggregated individual preferences. Collective values are mostly intangible, but tools for estimating these values are not well developed. Often there is no single or 'correct' answer. For example, market, welfare, survey or revealed preference methods can all be used. Ethical considerations of 'fairness' and 'justice' may also be important.

Environmental benefits are also seen largely in a collective sense because of the understanding of ecology as a science of systems, rather than of units. For example, the division between individual and collective values is similar to the difference between trees and a forest. Aggregated demand and usage can be readily converted into asset value for green infrastructure if the demand for both the trees and forest can be quantified.

Institutional values are the rules and norms that govern how a particular set of actions are carried out, and often collectively represent community and organisational values. For example, the institutional role of local government is to provide a range of services to the community, many of which can be delivered by green infrastructure. The market is another institution with a set of over-arching rules and behaviours that does not necessarily have the same aims, and left to its own devices would fail to provide all the benefits a community requires. This is a form of market failure which is a recurring theme within ecological economics.

The links between different institutional rules and their influence on how non-monetary values are represented in decision-making can be assessed and the different types of 'currency' used can be identified using various methods of institutional analysis. Network analysis and network-actor theory can be used to determine relative weightings of different values within a city's ecosystem service network (Ernstson, 2013). In that sense, values can be readjusted and realigned to involve neutral or even antagonistic actors within a system; for example by using GI to produce productive public space from an area that was regarded as a waste and drain on resources. Matthews et al. (2015) look at institutional planning regimes around risk reduction, suggesting these regimes' path dependence is a barrier to climate change adaptation when flexibility and innovation are needed. Angelstam et al. (2013) discuss the diagnosis of social-ecological systems using transdisciplinary research.

Finally, one of the largest controversies about the very different values produced by GI is how they are aggregated. For example, Fisher et al. (2009) state that in considering conversion of a wetland, adding the benefits of nutrient cycling, water regulation and recreation in a cost-benefit analysis would amount to double counting. We disagree and see them as distinct values with different beneficiaries. They also state that the final benefit in a systematic analysis that traces intermediate and sustaining values is the one that matters, but interpret this narrowly as marginal improvements to human utility (Fisher et al., 2009). Here, we are arguing that the flow of benefits is much more extensive than that.

The linkages between individual, community and institutional values and the benefits that address them are fully accepted in some areas of policy. For example, the ratio of public spending and student fees in the Higher Education Charges Scheme (HECS) was based on the notion of how public and private benefit could be apportioned in a higher education funding model (Chapman, 1997). The benefit of higher education to the individual can be realised through higher income and the benefit to society is through increased wealth and productivity. GI can do exactly the same thing.

The contribution of green infrastructure to resilience to changing climate risks, an aim of this project, is likely to be at all three levels. Personal resilience is provided by improved health and welfare. Community resilience can be assisted through the role of green infrastructure in place making, by providing meeting places and 'softening' public area, and reducing the impact of extreme events. Community and institutional values are interdependent, especially where institutional values and aims are directed to the welfare of individuals and communities. Green infrastructure can contribute to this by giving a sense of place, providing public meeting places and representing a range of cultural and spiritual values in outdoor settings.

Recommendation 6

Key issues that need to be part of the framework include how the following can be managed:

- individual and collective values,
- public and private assets,
- tangible and intangible values, and
- the distribution of benefits.

Building on Recommendation 5, we have addressed individual, community and institutional values in more detail, building on the links and differences between them. Individual benefits are centred on markets and utility, but not entirely, extending into intrinsic benefit. Community benefits are shared values and interactions. Institutional benefits sustain the goals of institutions and support both individuals and communities. Each requires a different system of valuation, but all play a part in contributing to and benefiting from urban green infrastructure.

Valuing assets

Worldwide, there is a trend to improving asset management through asset registers and forward planning to schedule asset renewal. Research of asset managers' experience is showing the potential for savings and improvements in service delivery (McGraw-Hill Construction, 2013). Within Australia, conventional municipal asset registers include parks and land, but often the built component and the land itself is included on the asset register. The other area where green infrastructure is represented is in stormwater and drainage systems that have a GI component.

The Victorian infrastructure study in 1998 was the first coordinated survey of infrastructure assets conducted in Australia (Burns et al., 1999). The two areas of green infrastructure it identified were parks and drainage. The study projected asset renewal needs over 1997–2012 concluding that parks was would comprise 4–5% of the demand for infrastructure renewal requiring a $176 million investment. This study also identified the lack of dedicated funding for infrastructure renewal, citing its dependence on an expanding rate base, itself largely dependent on population growth. This lack of dedicated funding was again raised in the recent state auditor's report on local government assets (Victorian Auditor-General, 2014).

In 2010, the Municipal Association of Victoria (MAV) set a target for councils to achieve a 'core' level of maturity in asset management, to be assessed using the National Asset Management Assessment Framework (Victorian Auditor-General, 2014). This framework is acknowledged to have some weaknesses that need to be reviewed. Some councils are more advanced in applying it than others (Victorian Auditor-General, 2014). Whether GI is considered a core asset by a specific local government body will depend on their resources, the place of GI within their service and delivery portfolio, and the current level of asset management and level of acceptance of sustainability issues.

Like all infrastructure, the full benefits from green infrastructure will not be realised unless the assets themselves are in good condition. However, the lack of dedicated funding for all infrastructure and the large gap in financing infrastructure renewal, suggests that adding green infrastructure may add to that burden and potentially widen the infrastructure funding gap. The other drawback hampering the recognition of green infrastructure, is that the benefits are seen as delivered for free. Therefore, they are not perceived as part of a deliberative investment cycle providing social environmental and economic services. One aim of the framework is to make these links explicit and visible.

Classes, subclasses and types of green infrastructure can be based on those developed for local government for conventional infrastructure, but can be expanded to account for the different types of GI. Table 3 shows asset classes and sub-classes developed for local government in Western Australia, with those that relate to GI emphasised. This shows considerable overlap between conventional and green infrastructure consistent with the application and benefits of GI.

Assets can be linked to goods and service delivery by using an asset valuation and maintenance program that accounts for infrastructure development, maintenance, upkeep and replacement. These are linked to specific service levels. By adopting life cycle investment, an asset management program will be focused on sustainable service delivery. Although such programs are used mainly for conventional infrastructure, they have been applied to street trees in Hobsons Bay (Hobsons Bay City Council, 2007), green infrastructure has been built into Marrickville Council's Asset Management Policy and Strategy (Marrickville Council, 2013) and stormwater in a range of places (Alexandrina, SA; Gold Coast, Qld).

Table 3. Local government asset classes and subclasses with those that have a component of GI emphasised. Modified from the Department of Local Government, Western Australia (2011).

Local Government asset classes	Sub-class examples
Land	Reserves, botanical garden, parks, sportsground and playing fields, landfill sites, cemeteries and other land assets.
Buildings	Administration buildings, animal shelters, libraries, public toilets, halls, heritage listed sites and other building assets (e.g., green roofs and walls).
Infrastructure	Road networks (sealed, gravel, reseals, permeable) including car parks, pavement (permeable), seal, kerb and channel, drainage, traffic management, furniture and signs, lighting and paths. Drainage networks (including open channel storm water drains), flood mitigation networks, water supply network, sewerage networks (including waste treatment facilities). Bridges, airports, wharves, piers, jetties and pontoons. Infrastructure on parks, gardens and reserves, tunnels, retaining walls, sea and river walls and canals, and other infrastructure assets.
Information Technology	Hardware. Software (GI specific programs and monitoring). Communications. Application specific technology.
Plant and Equipment	Vehicles (including corporate fleet, service vehicles e.g. rubbish collection vehicles/ranger vehicles, works vehicles, heritage plant). Equipment (including fixtures and fittings, furniture, street cleaning equipment, roads/paving equipment, parks equipment, heritage equipment, library books).
Other Assets	Off road paths, beaches, urban open space, street scapes.

The simplest way to value infrastructure assets is according to the cost of replacement. Enduring assets should not be depreciated in the same way as plant and machinery, which has a finite operational life. Infrastructure can be allowed to depreciate through lack of maintenance or be extended long beyond its design life by continued upkeep and renewal (Burns et al., 1999). It is also often aligned to specific levels of service, which cannot be met if infrastructure is allowed to degrade. Its replacement value will remain roughly the same in real terms if replacement costs follow the inflation rate, unless reconstruction costs rise faster, which is a real risk.

Walker and Jones (2012) surveyed public and private infrastructure asset managers to determine their preferred method of infrastructure reporting. These were assessments of the physical condition of assets, combined with current estimates of costs to bring to a satisfactory condition; and the combination of written-down replacement costs, condition assessments, and current estimates of the cost to bring assets to a satisfactory condition.

The latter was the most preferred option and links infrastructure condition to service delivery. This is vitally important for green infrastructure, which is more dynamic than most conventional infrastructure. Its condition at any time is important for understanding levels of service delivery, stage of development, potential stress factors and senescence. Replacement cost is also problematic for GI with a growth component. Valuing GI cannot be straightforward replacement if it is advancing stages of growth from juvenile to mature. For example, street trees have finite lifetimes because of the safety aspect of needing a sound structure whereas nature parks have planned lifetimes greater than a century.

Existing methods for asset valuation relevant to GI are:

- Fair value, defined as "the amount for which an asset could be exchanged between knowledgeable, willing parties in an arm's length transaction" (Australian Accounting Standards Board, 2014a). If there is no evidence of market price due to rarity or limited utility to another buyer, then depreciated replacement cost or future value of benefits can be used.
- Value of land with restricted uses. Land under restricted use can be valued according to that use rather than at market price. These include parks and gardens, national parks and reserves that are held for public benefit, vacant Crown land, and council reserves and parks (Australian Accounting Standards Board, 2014a).
- Replacement/reproduction costs. Replacement cost is a challenging concept for green infrastructure that is ecologically complex because of the time and effort required to re-establish it, if at all possible. For that reason, highly complex ecosystems are considered irreplaceable on human generational timescales. However, simpler systems and the engineering structures that may accompany GI have more established methods available. Valuation can also consider foregone benefits as part of recovery.
- Fair value for biological assets. Most biological assets are equivalent to bearer biological assets in the *Agricultural* guidelines (Australian Accounting Standards Board, 2014b), but mainly offer services rather than produce goods. The valuation of biological assets needs to take in their condition, stage in the life cycle and exposure to risk. Depreciation (appreciation) rates need to take in stage of growth, condition, expected life and future value of benefits.

GI will also be newly established, existing GI rejuvenated or pre-existing. Conventional establishment costs may not necessarily apply to pre-existing GI, so may require an approach that accounts for investment, operating costs plus a given yield in terms of benefits, or shadow-priced using standard establishment costs, plus maintenance. The latter methods would be used to assess the value of pre-existing GI, for the purposes of assessing a council-wide asset base, particularly if insurance is to be organised, or if potential loss (environmental risk) was to be underwritten. Examples are provided in Table 4.

Table 4. Type of green infrastructure, asset valuation method and replacement cost methods for different types of GI.

Type of GI	Asset valuation method	Examples and notes
Built, non-growing or very short establishment period	Establishment and maintenance costs over lifetime	Non-growing may have low maintenance requirements, but biological assets will need regular maintenance; e.g., rain gardens, green walls.
Built, growing, long establishment period	Establishment and maintenance costs over lifetime	Written-down replacement cost is establishment and maintenance to point of loss plus foregone goods and services; e.g., wetland, urban forest, street trees.
Gifted, growing	Asset value of establishment is transferred, maintenance costs over lifetime added	Written-down replacement costs as above.
Pre-existing GI	Cost to bring to satisfactory condition, maintenance costs over lifetime added	Written down replacement estimated cost of establishment to pre-existing condition plus refurbishment costs; e.g., bushland parks, nature reserves.

Recommendation 7

In developing asset registers for green infrastructure, existing asset classes can be used and accounting standards adapted. However, sufficient differences remain that that require standard methods for GI asset valuation to be developed. The framework needs to start with existing classes as a baseline but provide sufficient flexibility to develop.

Developing asset management processes for GI can yield similar benefits to those identified for other assessment management processes, but the capacity of a local government body is also an important factor that the framework needs to take into account.

Assessing benefits and social returns

Within the scope of this project, the primary benefits being assessed are those provided by adaptation to climate change, but a full assessment also includes the positive benefits of increased ecosystem services because these can also contribute to resilience. Therefore, there are two paths to follow: a direct path through adaptation measures and an indirect path through increased resilience. Both will offer benefits, but the latter is currently impossible to quantify.

If the benefits of conventional infrastructure can be readily calculated because they are better understood, and green infrastructure can only be given a partial calculation, because not all the benefits have been identified and quantified where possible, then GI is at a disadvantage. Addressing this disadvantage is a major motivation for this project.

The distribution of benefits from GI is important to understanding its value, especially as to how public and private benefits are distributed. This extends beyond the relationship between council and community, taking in business and industry and other levels of government. The distribution of benefits also varies widely in space and over time. Beneficiaries include the local community who have access to and use the infrastructure, visitors and the broader community. Understanding who the beneficiaries are can also indicate potential sources for co-funding and other kinds of support.

Spatially-distributed benefits can be both direct and diffuse. For example, removal of pollutants such as PM2.5 and ozone by trees have their greatest benefits at the local scale, but will also produce lesser benefits city-wide. The benefits of carbon sequestration are even more diffuse, where there is a local (shadow) price for carbon, but the benefits are shared globally extending to future generations.

GI can also generate benefits that council will have partial or no ownership of, but where it may have some form of control or influence. A council is responsible for green infrastructure on its own property and for developments that are bequeathed to council. However, the interconnected nature of green infrastructure may require local government taking an integrated approach incorporating public land and private land with a variety of owners. This will require additional effort on the council's part, including transactions between public and private institutions, and expenditure by private landowners and developers as part of planning regulations.

Benefits can accrue to individuals and to communities but can also fulfil institutional aims. For example, if a population becomes healthier through both passive and active utilisation of open space, then this helps meet the policy goals of government agencies responsible for community health and wellbeing. These are often state or federal government roles.

The long-term benefits of human health and welfare and related intangibles are measured as social returns. These public benefits are consistent with Principle 2 of the Building Australia Fund guidelines for making the case for infrastructure investment (Box 2). Social returns on investment are described as the social, environmental and economic returns that lie beyond the normal cost-benefit structure of cost-benefit analysis. Social returns imply public benefit but is not always the case because of the many different benefits provided by GI. For example, a single piece of GI can provide public and private benefits to individuals, public benefits to communities, and those that also address institutional goals.

Box 2. Building Australia Fund Evaluation Criterion 2

Principle 2: Projects should demonstrate high benefits and effective use of resources

Evaluation Criterion 2: Extent to which proposals are well justified with evidence and data.

a) Proposal should demonstrate through a cost-benefit analysis that the proposal represents good value for money.
b) Project should indicate an expectation of long-term public benefits, taking into account economic, environmental and social aspects of the project.

The lifetime of the good or asset influences what a reasonable return may be and influences what we are prepared to pay up front. A computer is only expected to provide a return over 3–5 years at the outside, a car 7–10 years and a house roughly 50 years. As a piece of infrastructure, though, if a house is continually maintained to preserve its value, its value as an asset will be maintained in approximately real terms, giving rise to the view that maintenance costs could be considered as part of the capital outlay required to maintain asset value, or be used in tools such as condition-based depreciation that reflect asset value (Burns et al., 1999).

Some values are additive. For example, an element of GI such as a street tree may provide benefits to individuals through shade and pollution control, to the community through adding to a sense of place and general climatic amelioration, and may benefit adjacent businesses through increased economic activity, adding a private element. A wetland may provide all the above in addition to conservation benefits, increased amenity and recreation.

Benefit transfers may also take place over long periods of time, where growth and maturity in GI can result in a range of immediate, intermediate and long-term benefits. The hypothetical example below shows a combination of increasing values and value transfers as economic returns can result from the initial investment, but only after the services have become mature enough to support higher visitation rates and provide sufficient amenity. Such benefits are usually too long-term for conventional cost-benefit analysis, but can be valued into infrastructure benefits via the use of options and quasi-options.

Hypothetical park and wetland development

- Stage 1 benefits (1–2 years): increased visitation rates, active and passive benefits, personal health and wellbeing, community wellbeing in sense of a place to meet, flood mitigation.
- Stage 2 benefits (3–8 years): increased fauna through birdlife and insects, increased visitation rates through generation of shade, cooler environment within the park through water re-use, mobile and fixed food and drink, commercial exercise and recreation, flood control and increased water quality, visitors from outside local area (increasing draw power).
- Stage 3 benefits (8+ years): canopy benefits for the users of the park and immediate surrounds, increase in adjacent property prices and lower energy costs, adjacent business location and growth, festivals and events (formal and informal).

A comprehensive and ongoing portfolio of investment in GI within a single LGA may create a flow of benefits that could increase long-term social returns, and improve the returns from conventional infrastructure by reducing its negative impacts. It will also produce private benefits of increased property prices, and potentially lower energy and water inputs. Increases in community satisfaction will improve general social and economic productivity, and greater amenity in public open space will create opportunities for adjacent businesses. However, there is insufficient knowledge to value these returns on a project-by-project basis, or do this at the LGA scale. While many councils are making large-scale investments, at present the rate of return remains unknown.

Many individual projects have been able to get approval for projects by emphasising experience and local evidence (e.g., good parks bring in more people), but the calculation of social benefits is often required for public investment purposes when GI projects are competing for funding with projects that have a clear monetary return. It is also useful for estimating other beneficiaries and potential sources of co-funding.

Recommendation 8

Social returns from green infrastructure investment are difficult to assess. The framework needs to build in a structure for calculating social returns over the life of a project that can be built on over time. Clearly identifying different types of beneficiary is another task that needs to be incorporated.

Valuing green growth

The largest difference between green and conventional infrastructure is its organic character. This creates a different benefit-cost relationship to that of normal infrastructure. This is illustrated by the following relationship, which is based on the growth of a Hackberry tree, a North American relative of the elm tree as an example (adapted from McPherson et al. (2006)). The two benefits simulated are stormwater interception and pollution interception, both proportional to the size and canopy of the tree (Figure 3). Pollution interception is for PM10 and PM2.5, invisible airborne particles that pose a health risk, taken from Jones and Ooi (2014). Three forms of discounting are imposed: zero, 3.5% per year and 5% per year. Discounting is the present value of money at a given time in the future (discussed in the next section).

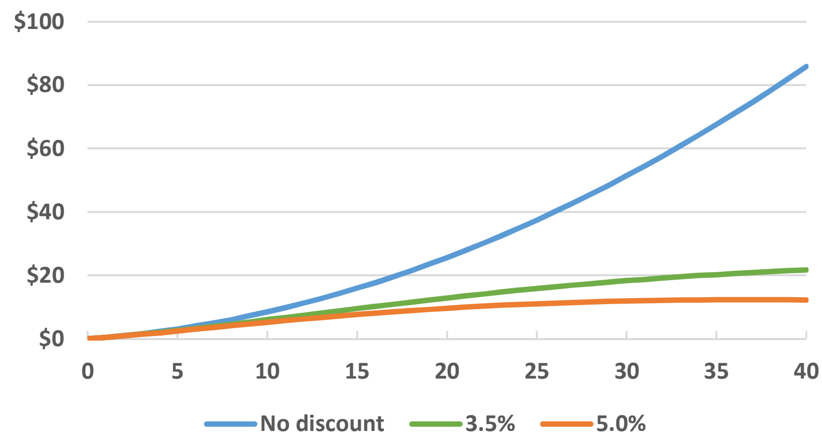

Figure 3. Hypothetical changes in annual value of stormwater, PM10 and PM2.5 interception and for a Hackberry tree based on $1:50 per kL stormwater interception and PM10 and PM2.5 interception for a relatively vulnerable population (age and respiratory disease). PM10 and PM2.5 particles are small airborne particles that pose a health risk, values from Jones and Ooi (2014).

A newly planted tree will require up-front establishment costs, short-term follow up and regular inspection and maintenance. However, the benefits associated with growth may take some time to be realised. If conventional social discounting of 3.5–5% is applied, then the benefits provided remain positive, but are greatly diminished.

Benefits based on physically-limited capacity will either grow to capacity or remain constant in terms of their real price over time. For example, pollution reduction by a tree will grow as the tree grows, then remain relatively constant over time. Non-exclusive benefits that influence growing communities may increase over time if the number of people benefiting increases, through population growth in the target area. Non-exclusive benefits of this type include flood mitigation, visual amenity, shade and temperature amelioration. The development of the iTree model in the US (Nowak et al., 2006; Nowak et al., 2008) and its adaptation to Australian conditions (Caffin, 2012) is a key part of assessing green growth at the individual tree scales (the US version assesses the urban forest also). Further models would be needed to assess GI at the urban forest and stream network scales.

The history of Greater Melbourne shows that green infrastructure is highly prized at the community level. It is central to the development of a culture of place in inner Melbourne and throughout the urban area. This points to the ongoing development of acquired value, which may contribute to a cultural economy based on tourism, events and internal visits. This shows the potential to obtain benefits over intergenerational timescales, providing maintenance and renewal is also supported over that time.

The continual improvement of green infrastructure in cities, with its multiple benefits, offers the opportunity to provide ongoing increases in intangible values to individuals and communities. These values are being affected by changing environmental risks, which are a combination of changing landscapes due to urbanisation and climate change.

Recommendation 9

Valuing green growth is a critical part of quantifying the value, especially the benefits, of green infrastructure. Understanding the dynamic nature of growing systems, cost effectiveness of maintenance, the increase in benefits over time and the useful lifetime of living systems as part of a full life-cycle assessment is necessary for maximising its potential. These tools need to be further developed but will be included in the framework in prototype form.

Social discounting and rates of time preference

To non-economists, discounting doesn't make a lot of sense. It basically asks "what is the value of doing this now as compared to later?", and "Do I want to do this, or something else – which is the better choice?" Economics is trying to provide a rational answer to these questions, but the conclusions are often highly contestable.

Discounting does two main things: it takes the basic human preference for having something now compared to later, and it allows for the present value of future returns to be contrasted with the up-front investment costs and upkeep. This blends psychological and behavioural traits with economic instrumentalism. On the benefits side, values can be expressed as dollars, from an ethical perspective, or a combination of both. This pits orthodox economics against behavioural economics and the ethics of value against instrumental values. Combining these four aspects within a single discount rate means that discounting in the field of ecological economics remains highly contested.

Social discounting is applied where an investment is made in anticipation of social returns. For example, a city may build a park attracting more visitors, increased health and wellbeing in park users, a cooler environment in and around the park, and increased social connections. Planting long-lived trees and stormwater infrastructure suggests that a design life of 70–100+ years is being envisaged, so that the benefits extend over intergenerational lifetimes.

Social discounting has two main functions within economics, generally grouped under prescriptive and descriptive headings (Arrow et al., 1996; Harrison, 2010). The prescriptive function is normative, addressing equity concerns, the scarcity of environmental services in the future and the nature of the anticipated benefits. The descriptive method looks at the opportunity cost of investment in GI as compared to other potential investments and to the cost of capital. For local government investing its own funds, this means contrasting how much they have now to invest compared to later. In terms of prioritising from a range of decisions, one question council can ask is: "which of these projects provides the highest rate of return?" This may not necessarily be monetary, but could satisfy a broad range of values.

Discount rates are usually positive (and their effect of future value, negative), because they reflect a preference for consumption today over consumption tomorrow (temporal discounting) – a dollar today is worth more than a dollar tomorrow. Discounting is also a measure of opportunity cost for available funds – in a growing economy with inflating prices, sensible investment will yield better returns than leaving the money under the mattress.

Depreciation rates – what something will be worth in future compared to now – vary widely for different products. Figure 4 shows three goods that depreciate at different rates based on their useful lifetimes. Some of the urban green infrastructure in Greater Melbourne is over 150 years old, other GI is natural or modified natural habitat with much older origins, and much of what is being developed now is anticipated to last for generations. This introduces the theme of intergenerational timescales into planning.

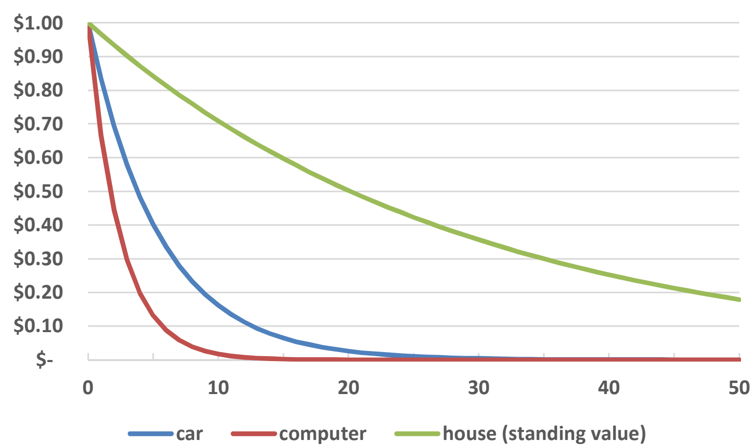

Figure 4. Representative rate of time preference or discount rates for a car, computer and house.

The size of the discount rate determines how much the future is discounted with respect to the present. High profit rates and short investment timelines warrant high discount rates, whereas lower returns and long investment timelines warrant lower discount rates. Characteristics of green infrastructure that fit the second profile include:

- many of the returns are intangible, being social and environmental rather than economic so are subject to preferences other than marker preferences,
- many of the goods and services provided have low substitutability with manufactured goods and services, and
- sustained returns over long periods are expected.

If these conditions are present and capital value is maintained, then low discount rates are justified (Quiggin, 1997).

For intergenerational timescales, two aspects of discounting need to be considered. One is pure discounting, sometimes 'the pure rate of time preference' (Arrow et al., 1996). The other is utility of consuming goods and services now as compared to later. Ramsey (1928) developed discounting to assess the wealth effect, or the marginal cost of consumption of a person now compared to a person in the future, when they may be wealthier than today. He considered that pure discounting of future generations compared to today's was unethical, a debate which continues to today, catalysed by the Stern Review on climate change (Neumayer, 2007; Stern and Treasury of Great Britain, 2007; Weitzman, 2007; Yohe and Tol, 2008). Some economists maintain that social discount rates should be revealed through market behaviour (descriptive social discounting), but we reject this proposition here because of the points concerning GI as a special case made earlier. Markets in general do not operate under those conditions and therefore, often fail, as is the case for climate change.

When considering intergenerational equity, the treatment of the discount rate is crucial (Ackerman and Stanton, 2011). For example, if people in the future matter less than those of today, we may consume natural assets faster than their renewal rate, because people of the future matter less, or because they may obtain their wealth and welfare from another source. This becomes ethically problematic if that consumption is irreversible. Cities are built to last, but also need constant renewal. Nature is also renewable and cities can utilise nature as part of their renewal.

Substitutability and irreversibility also have an effect on discount rates. The kinds of goods and services consumed and the future value of green infrastructure supplying those, also needs to be examined. Goods and services that cannot be sourced from elsewhere, or have low levels of substitution, warrant lower discount rates. Under conditions of low substitution between environmental and manufactured goods, and strong sustainability, where substitution over time is problematic, discount rates are hyperbolic, starting fairly low and declining over time (Traeger, 2011). Guéant et al. (2012) show that environmental amenities, the degree of substitutability between consumption and environmental quality, the degree of risk aversion, and the rate of change of these attitudes as natural and man-made resources evolve over time are all important for discount rates and how they evolve. Gollier (2010) examines ecological discounting, providing a discount rate for biodiversity of 1.5% compared to a discount rate based on consumption of 3.2%.

It is also reasonable to expect that social values, such as individual wellbeing, will maintain their real value over time. This is, a person’s wellbeing in 2050 is the same as a person today. Wellness, as an aspect of quality of life, is important and may even increase in importance as people age, so could be considered to maintain its real economic value. If GI can provide the same level of service to a community over long timescales while maintaining its asset value, then its asset/return ratio will not change, or only very slowly. If GI grows, offering a higher level of service, or the population in an area increases but enjoys the same non-exclusive goods (e.g., more people enjoying the same park), then social returns will increase. This is a practical aspect of the ethical argument on intergenerational equity mounted by Ramsey (1928) and others.

Other forms of discounting may also affect how discount rates are used. Spatial discounting suggests what is further away matters less (Pearce et al., 2003; Shwom et al., 2008). This is reflected in hedonic pricing studies which measure the effect on house prices and their distances from a park (Tyrväinen and Miettinen, 2000; Waltert and Schläpfer, 2010). Risk tolerance and spatial and temporal inequality are only weakly correlated so need to be considered separately (Atkinson et al., 2009; Guéant et al., 2012).

Ackerman and Stanton (2011) argue that all analyses should include a statement explaining the choice of discount rate. They further suggest that when the case of a particular choice of discount rate is weak, the discount rate should be varied and multiple results reported.

The long-term values invested in parks and open space that have been integrated into urban areas (developed open space), has implications for how values are discounted over time in conventional economic assessments.

Recommendation 10

An examination of social discounting theory and methods suggests that urban green infrastructure should have prescriptive discounting methods and low discount rates applied because of the:

- long time frames involved,
- contribution to social welfare and other intangible measures,
- limited substitutability and irreversibility, and
- local government funding being tied to low rates of future consumption.

Social discounting methods modified to account for ecological factors are most appropriate for economic assessment, but some of these modifications are experimental and not yet widely used in practice. Further testing and sensitivity analysis is recommended.

Application of social discount rates

When social and environmental benefits are considered, especially at the community scale, the use of social discount rates is widely recommended (New Zealand Treasury, 2008; Harrison, 2010; HM Treasury, 2011). The history of social discount rates in Australia is summarised in Jones et al. (2013). The issues of discount rates with respect to sustainability are discussed at length in Quiggin (1997).

Australian social discount rates in practice are some of the highest in the developed world. The Commonwealth's Office of Best Practice Regulation (OPBR) recommends rates around 7% real (before-tax rate of return on private investment, the investment or producer rate), with sensitivity testing at 3% and 10% (Office of Best Practice Regulation, 2014) based on Harrison (2010). This also sets the Commonwealth Government benchmark for regulatory proposals (Office of Best Practice Regulation, 2014).

Of the states, the NSW Treasury also recommends using a real rate of 7% with sensitivity testing at 4% and 10% (New South Wales Treasury, 1997); the Queensland Treasury used to recommend 6% but now requests that it be consulted over the appropriate rate (mainly to determine the appropriate risk premium) (Queensland Treasury, 2006); Infrastructure Australia recommends cost-benefit studies submitted to it should use 'real risk free' discount rates of 4%, 7% and 10% (Infrastructure Australia, 2008); and the Department of Health and Ageing and eHealth Council (2003) recommends evaluating environmental health policies with a discount rate of 5%, with sensitivity tests ranging from 3% to 7%.

In a research report on environmental regulation, the OPBR assumes that the 'true' discount rate is in the range 3% to 10% (see above) and recommends using a sliding scale of reducing rates over time (Commonwealth of Australia, 2014). The timescales are clearly based on the UK Treasury Green Book discount rates (HM Treasury, 2011) that share the same time periods but the Australian rate is roughly twice the UK rate (Table 5).

The UK Green Book rate is based on the Ramsey (1928) formulation that accounts for the rate at which individuals discount future consumption by applying a pure rate of time preference and allowance for catastrophe (fatalism, or we have no economy). This is modified by growth in per capita consumption and how that translates into general consumption. This formulation yielded the 3.5% declining rate shown in Table 5. The UK government uses this rate to assess the long-term social benefits of policy decisions.

The Australian rate is based on Harrison (2010) who says the following:

> *Unless there is a reason to believe that transfers to the future from one project are less easily misdirected than transfers from others, the chance that an intervening generation will break the chain of investment does not favour adopting low return projects.*

This may be the case for legislation but is not the case for a great deal of urban open space, as shown by history. The chain of investment tends to continue over time and long-term returns are being achieved, but high discount rates imply those returns are worth next to nothing. Is the environment worth half in Australia of what it is in the UK? For government policy purposes, apparently it is, based on the Office of Best Practice Regulation (2014)'s recommendations.

Table 5. Long-term discount rates from the Australian Office of Best Practice Regulation and the UK Treasury Green Book showing end of period Net Present Value as a percentage of the initial investment.

Australian Office of Best Practice Regulation						
Period of years	**1–30**	**31–75**	**76–125**	**126–200**	**201–300**	**301+**
Discount rate	7.0%	5.4%	4.8%	4.3%	4.0%	3.7%
End of period NPV	13.1%	1.2%	0.1%	0.01%	0.0001%	
UK Treasury Green Book						
Period of years	**1–30**	**31–75**	**76–125**	**126–200**	**201–300**	**301+**
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%
End of period NPV	35.6%	9.4%	2.7%	0.6%	0.1%	

Quoting Harrison (2010) here is not meant to imply that urban GI is low return, but many returns from GI do start small and grow over time. High discount rates will discourage projects that do not have immediate high returns. To show this, Figure 5 shows an example of a park that costs $1 million and has a 2.5% net return immediately (e.g., park user benefits) and a potential 2.5% that grows from zero over 40 years, representing the benefits of stormwater and pollution interception from growing vegetation. At maturity, this equals a total of 5% or $50,000 per annum nominal return on the initial investment and is assumed to be net of maintenance and upkeep. After 100 years the Australian park has only recovered 47% of the initial $1 million investment, whereas the UK park would recoup its investment in 84 years. Over a 60-year period, the Australian park would return half the benefits of an equivalent UK park. Although, a 5% nominal return from direct benefits and co-benefits is quite low, the example shows how sustainable investment is being discouraged by current government guidance.

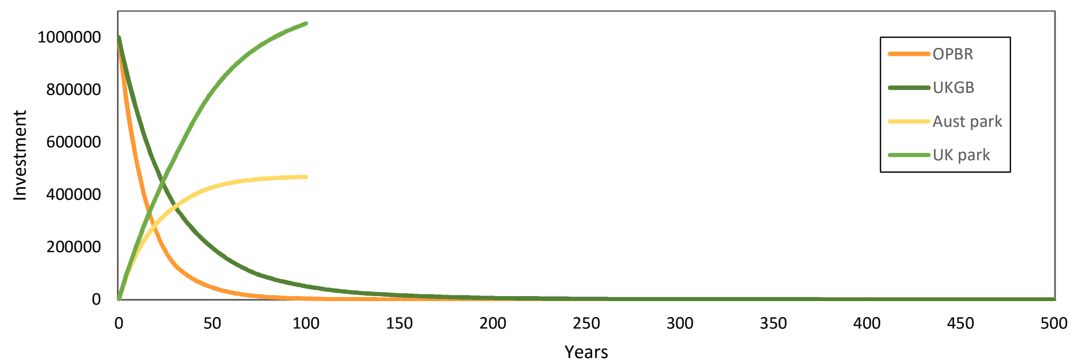

Figure 5. Net present value of $1 million using long-term environmental discount rates from the Australian Office of Best Practice Regulation and the UK Treasury Green Book over 500 years, shown with a hypothetical return on a park of 2.5% immediate and 2.5% achieved after 40 year's growth, under a UK and an Australian scenario.

For conventional infrastructure, recommended rates are often in the 3.5% to 5% range. For example, the Victorian Competition and Efficiency Commission (2007) recommends 3.5%, "a recent average of the ten-year Commonwealth bond rate to determine the risk free opportunity cost of capital"; and the Victorian Department of Treasury and Finance (2007) endorses 3.5% (but adds a risk premium of 6% when assessing private sector bids for public-private partnerships). The South Australian Treasury (2007) also uses the long-term government bond rate as a risk free rate, estimated to be 5% real. The Department of Treasury and Finance Tasmania (1996) recommends the long-term Commonwealth bond rate plus 1% as "the long-term cost of funds to the Government".

The other factor that influences the financing of GI, is that grant money requiring council co-funding in projects often needs to be applied for and spent within a certain time period. There is an opportunity cost if this money is not utilised, so that implicitly can also justify lower social discount rates and/or returns based on qualitative values, because of reduced risk of return to council investments.

All advice on the application of social discount rates suggests that the appropriate response is to conduct a sensitivity analysis (Commonwealth of Australia, 2010; Harrison, 2010; HM Treasury, 2011; Office of Best Practice Regulation, 2014). Harrison (2010) states that because cost-benefit analysis (CBA) uses the yardstick of efficiency, it is not structured to address equity and distributional effects, but CBA is being used in many situations where such considerations need to be made. If CBA or its variants, discussed in the next chapter, are to be used for GI, then only social discount rates at the lower end of those currently in use are appropriate.

Recommendation 11

Rates of social discounting in Australia are generally higher than those applied elsewhere. The use of discount rates modelled on the UK Treasury Green Book (3.5% pa decreasing over time), or even lower, is recommended for green infrastructure with high intrinsic or acquired values. Components of green infrastructure that substitutes for conventional infrastructure may apply general social discount rates for infrastructure. Social discount rates need to reflect the long-lived nature and high intrinsic value of green infrastructure and of the benefits it can yield over those timescales.

5. Current methods and tools

Valuation methods

From the discussion in earlier chapters, value-directed benefits can be allocated according to the following hierarchy:

1. Direct economic benefits with market values.
2. Indirect benefits that can be allocated a shadow or proxy price that sustain social and environmental values through areas such as social welfare and environmental health.
3. Acquired values with benefits ranging from direct to indirect but often convertible into dollar values.
4. Existence and other ethically-framed values.

Environmental approaches with so-called 'weak' sustainability contribute to the first category above and part of the second category. Strong sustainability will utilise all four categories. In this chapter we discuss a range of valuation methods that can be used for assessing individual, community and institutional benefits.

The following descriptions have been adapted from Keating and Handmer (2011), Jones et al. (2013) and Young and Jones (2014). A much more detailed description of valuation methods is in the literature review undertaken for this project (Symons et al., 2015).

Cost and benefit methodologies

Conventional CBA methods have been widely criticised for their restricted use to a limited set of values and their inherent assumptions of substitutability and weak sustainability. However, for the need to assess what might be a reasonable return on investment or to compare trade-offs or different options, some form of assessing benefits against costs is required.

In many situations, conventional CBA methods can be adapted to account for the uncertainties and long-time scales associated with green infrastructure, in part by modifying discount rates as discussed in the last chapter. It is possible to ranks these methods from direct to indirect by addressing the following levels of benefit:

1. Direct-use benefits with market values.
2. Direct-use benefits assessed with shadow pricing or preference methods.
3. Acquired values convertible into dollars.
4. Indirect benefits that sustain social and environmental values. These may be converted into dollar-equivalent measures, ranked or assessed using multi-criteria analysis.
5. Option benefits that relate to potential future uses.
6. Existence and other ethically-framed values.

Costs for new GI are ideally calculated with ongoing maintenance required to meet defined service levels as detailed in the previous chapter. Ideally, they also need to be financed accordingly. The development of physical resilience will not be delivered by any single element of GI, but by projects and programs which modify the environment sufficiently to ameliorate the environment, intercept rainfall or stormwater and generally reduce the impact of extreme conditions. Assessing the value of these benefits under changing conditions may require a significant amount of work.

The following are tools that can be used to modify CBA to address the range of needs above. This list is not exhaustive and a much more comprehensive list can be found in OECD (2006).

Shadow pricing

Shadow-pricing methods estimate the value of an asset or commodity by the benefits associated with closely linked economic variables. For example, property prices are higher near open space providing shadow prices for the benefits of open space amenity in urban settings (Hatton MacDonald et al., 2010). It is a method for assessing mean conditions and not suitable for assessing rapid change. However, it has great potential for assessing the co-benefits of adaptations where social and environmental outcomes are important.

Preference methods

Three formal methods for eliciting value preferences are willingness to pay (WTP), willingness to avoid damages (WTA), which are both stated preference methods (what people say) and assessments of how people behave in given circumstances, or revealed preference. These methods are subject to framing effects where the first two are asymmetric, but measure the same thing (Bateman et al., 2009) and the second only deals with past but not future values. An example of revealed preference is when travel costs are used to value visits to a location such as a park or beach – the average cost paid then becomes the value a person obtains from each visit.

WTP and WTA are often used to measure intrinsic value, but are not recommended for that purpose as open-ended questions about what a person may pay to preserve nor not lose a benefit are considered unreliable. Such methods are more reliable if linked to a bounded and clear transaction or payoff (Hanemann, 1991).

Benefit transfer

Benefit transfer is when the results of a valuation are transferred from one situation to a like situation in another place or time (Brouwer, 2000; Wilson and Hoehn, 2006). 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).

One web-based resource for sourcing studies is the Environmental Valuation Reference Inventory (EVRI: www.evri.ca). The toolkit helps the user define the service to be valued and identifies studies with potential for transfer. EVRI includes a database of more than 2000 environmental valuation studies. A similar searchable database has been compiled by the New South Wales Government Department of Environment and Climate Change.

Dealing with uncertainty

Probabilistic CBA is used when subjective probabilities can be assigned to futures covering the range of plausible change. Real options techniques, also called sequential analysis, minimize the 'cost of error' caused by uncertainty by testing what if outcomes (Hallegatte et al., 2011; Dobes, 2012). State-contingent CBA also builds flexibility into adaptation (Adamson et al., 2009), where alternative strategies designed to maximize returns or bolster resilience can be triggered based on a given set of signals (often called critical control points, or management thresholds). Again, this methodology is suitable for assessing rapid changes in conditions, but diagnosing the correct set of signals is important.

Other costing and evaluation methods

The following methods are generally used where benefits cannot be quantified in monetary terms and are selected by other means.

Cost-effectiveness analysis

Cost-effectiveness is used whenever benefits cannot be quantified in monetary terms, or does not need to be. Cost effectiveness may be required for the following reasons:

- A decision has been made on the basis of expediency, as policy or is required by regulation and the cheapest or most effective option is being sought.
- The benefits are self-evident and cost-effectiveness is common sense.
- The benefits and costs are incommensurate, but those costs are perceived as being less than the potential benefits over the long term. This consideration is most relevant to environment and social assets.
- The benefits of different options are considered roughly equivalent.

Ideally, costing will look at the whole project cost from R&D through to implementation. A weakness of this approach is that often the different options may themselves be incommensurate and the relative benefits uncertain, so 'effectiveness' is very difficult to measure. An example is where a town vulnerable to sea level rise, storm surge and groundwater contamination, may weigh up building a sea wall and safeguarding groundwater supplies as opposed to relocation.

Multi-criteria analysis

Multi-criteria analysis (MCA) is extremely flexible in approach. Two approaches can be applied: as the collective analysis of individual preferences or as a group-scale assessment. If quantitative, it will score options according to various criteria, resulting in a combined score that identifies the most optimal outcome. At its most qualitative, it can involve a room full of people with a given set of criteria making a subjective selection from a set of proposals.

MCA is vulnerable to the social constructions of the stakeholders making the collective decision. This can be dealt with by using a structured methodology that shows a significant difference from baseline conditions and clearly separates trade-offs. By conducting an institutional analysis (where the respective values of the different participants are made explicit in addition to the institutional value at play), much more well-informed decisions can be made. Hierarchical structures can also assign weights to different benefit groupings, within which individual benefits sit, as a means to structured ranking.

Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is particularly suitable to group decision making and is commonly used by decision makers in government and business. AHP does not prescribe a 'correct' decision, but rather AHP assists decision makers reach a decision that best suits their purpose within the problem's parameters. It provides a framework for structuring decision problems, representing and quantifying relevant factors, and relating those factors to the overall goal as well as evaluating alternative decisions (Saaty and Forman, 1992).

AHP initially decomposes the problem into a hierarchy of more easily comprehended sub-problems, each of which can be analysed independently. Once the hierarchy is in place, the various factors are systematically analysed and compared with respect to their impact on a factor above them in the hierarchy. In making the comparisons, decision makers can use data about the factors; however, they use their judgments about the factors' relative importance. Consequently, within AHP human judgments, and not just the underlying information, are used in undertaking the evaluations (Kayastha et al., 2013).

AHP converts the evaluations to numerical values that can be processed and compared over the whole problem. Numerical weighting is derived for each element of the hierarchy. This allows diverse and incommensurable factors to be compared to one another in a consistent way. This aspect distinguishes the AHP from other decision-making techniques. Finally, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action (Subramanian and Ramanathan, 2012).

Expert assessment

One way to gauge impacts and value where models aren't available or are too resource-intensive, is to interrogate experts in a structured manner producing a conclusion with a given range of uncertainty that can act as a vote of confidence in the underpinning theory, data and models – but through a socially-influenced filter (Brooks et al., 2005; Doria et al., 2009).

Stakeholder preference

There is a range of survey methods that can elicit peoples' psychological and cultural preferences in order to better understand social and cultural influences on valuing benefits (Reser et al., 2011). This is because simple ranking methods, project alternatives or options can be contrasted and ranked in order of preference as a measure of preferred value.

Institutional values

Institutional values are embedded in institutional rules and norms. Two sets of rules in particular will influence green infrastructure. The first set deals with the stated methods and processes that are in place to guide GI projects. The second set comprises the methods actually used by council employees and their collaborators to put projects into place. As part of the project analysis, we have been investigating both (Young et al., 2014b).

The analysis of institutional rules can be carried out at two levels. Rules can be interpreted at face value or at deeper levels where factors such as organisational attributes and culture influence how such rules are generated and/or interpreted. Communities of practice have rules as to how knowledge is generated, communicated and applied. Some of these will have a sound basis because they have been rigorously tested, but others may be rules of thumb or be taken from a 'like' process and adapted to suit the task at hand. These can be used to contrast green and grey infrastructure. By understanding this at the local government level, it will be possible to find ways to embed green infrastructure within the fabric of local government (Young et al., 2014b). A comprehensive analysis of institutional goals, norms and benefits linked to the benefits of green infrastructure will identify the institutions and organisations who receive a benefit from green infrastructure projects. They can then be identified as stakeholders.

Valuation tools

Valuation tools and frameworks that have been used in Australia include the i-Tree tool (Box 3) and INFFER (Investment framework for environmental resources) (Pannell et al., 2009; Pannell et al., 2010; Pannell et al., 2013).

Box 3. Valuing the urban forest

In 1990, Peter Yau developed the City of Melbourne amenity value formula to calculate the monetary value of urban trees. This has since been used successfully to acquire compensation for trees lost due to development, and has been adopted by other local government authorities in Australia.

Amenity valuations establish City of Melbourne's urban forest as having an approximate worth of $700 million. Valuing the urban forest solely on the basis of an amenity formula does not account for the environmental benefits provided by the urban forest.

The i-Tree Eco tool is a free, peer-reviewed software suite from the United States Department of Agriculture's Forest Service, which provides an urban and community forestry analysis and benefits assessment tool (www.itreetools.org/about.php). It provides a broad picture of the entire urban forest and is designed to use field data along with local hourly air pollution and meteorological data to quantify urban forest structure, environmental effects, and value to communities.

New York has used i-tree to evaluate that for every dollar they spend on trees, they receive a return of $5.60. In 2010, the Victorian Local Sustainability Accord provided funding to the Cities of Melbourne, Port Phillip and Moonee Valley to develop and contextualise the i-tree Eco tool for Australian use. The National Urban Forest Alliance (NUFA) and Arboriculture Australia have partnered as joint custodians of the i-Tree Eco Australia.

City of Melbourne has currently assessed over one thousand trees using i-Tree Eco.

INFFER is structured around cost benefit analysis, but often does not calculate monetary benefits, though benefits do have to be measurable. Conditions for assessing whether the project is feasible for assessment follow 'SMART' criteria (specific, measurable, achievable, relevant and time-bound) (Pannell et al., 2010). Asset valuation is scored on a scale of 1:100, which is elicited from stakeholders to ensure all values are represented. The framework contains assessments of uncertainty and risk, a public-private benefits framework, accounts for funding lags, adoption rates, technical feasibility and time-lag for benefits, and factors in discount rates and operating costs. Its main advantage is that it introduces a rigorous project management and economic structure into a working environment where such tools are generally not used in that way (Pannell et al., 2010; Pannell et al., 2013). Most of its application has been in the natural resource and land management sectors, working on environmental issues such as salinity management and land degradation.

Recommendation 12

The many different methods and tools available can be confusing. The framework needs to match different valuation methods with types of benefit (see Appendix A) taking account of:

- Ease of use.
- Data needs.
- Maturity of method.
- Confidence in the results.

Summary of systems in use at the local government scale

As part of the research program, four research workshops were undertaken. These comprised of three workshops undertaken with individual councils (Kingston Council, Moonee Valley Council and City of Melbourne) and one integrated workshop which included all the participating councils and other key stakeholders (Young et al., 2014a; Young et al., 2014b). During this process a number of barriers and opportunities were identified.

Innovation, and monitoring and evaluation were the two key areas identified as opportunities for improvement. Currently, the level of innovation depends upon the expertise of individuals within councils and it is not an explicit part of the operational processes. Identifying opportunities for innovation and clearly embedding it in the decision-making process will reduce the risk associated with green infrastructure projects and assets. It will also assist decision-making in areas of appropriate investment and management, largely by targeting information needs and managing uncertainty. However, identification of innovation can also create barriers in councils who have low risk appetites, and so needs to be actioned in strategic manner to enable activities.

Innovation is often limited within local government. Limited funding and an emphasis on efficiency tends to reinforce local government's traditional conservativism (Potts, 2009). The appetite for innovation goes hand-in-hand with the appetite for risk. This can be managed in part by case studies and worked through examples, to illustrate how innovation can be managed in a programmed manner. The development of additional monitoring and evaluation through the life cycle of all green infrastructure assets is crucial for the following reasons (Young et al., 2014b):

- Data describing benefits and services generated is needed to support future business cases, and for measuring and reporting the return on investment to the broader community.
- It will support the use of innovative technologies and ecological systems, where the benefits and processes supporting them may not be fully understood or there may be unanticipated outcomes.
- It is needed to support the effective management of living assets.
- Urban environments are subject to a variety of unpredictable pressures, so monitoring and evaluation of the condition and response of these assets and the services they provide is needed.

These tasks can be carried out within an asset management program, but require resources commensurate with the expected benefits gained from implementing the program. For smaller councils, this may depend on staff developing extra skills to use on the job. Trialling these methods in one or two projects can also provide relevant experience that could be scaled up at a later date.

Although green infrastructure assets provide social, environmental and economic benefits, these benefits are still not fully understood. As a result, the opportunities they offer are not fully realised. The task of a framework is to identify all relevant benefits, make clear the known links between services, values, benefits and methods for assessment within a structure than can apply new knowledge as it arises.

Key barriers identified in the workshops were a lack of long-term integrated planning, policy and inconsistent investment. Key needs were the development of appropriate valuation tools and operational mechanisms (policy, systems, funding) to develop, maintain, monitor and evaluate these assets. There was also a need for collaboration, knowledge development and ongoing education to support the changes needed and develop areas of practice.

All councils who participated in the workshops are developing initiatives to improve areas of operations such as project and asset management. This offers a key opportunity to embed green infrastructure needs into the changing operational matrix. Other areas of opportunity articulated during the workshops were (Young et al., 2014b):

- Greater inclusion of green infrastructure at the beginning of the development process for all types of infrastructure.
- Whole of life-cycle planning of new projects through an integrated asset management structure, with particular attention paid to the post-development stages.
- Improvement of ongoing monitoring and evaluation of green assets.
- Integration of innovation practice into the management framework, in particular reflexive practice where new knowledge is captured and shared.
- Development of more robust business cases through improved reporting practices and diverse assessment methods.
- Improvement of systems and tools already in use, such as current valuation and maintenance programs.
- Communication, engagement, ongoing learning and education in relation to the needs, use, benefits and value of green infrastructure.
- Clearer classification of assets.
- Greater collaboration between private, public and research sectors to enable further development in this field.

The final workshop highlighted the complexities of the valuation task and the need for systemic approaches to assess the multiple values attached to each action and asset. It also reinforced findings from the individual council workshops in relation to the need for long-term visions, collaboration, funding and policy to support effective implementation of project designs. Flexible and integrated management frameworks and structures were also seen as important, because of the length of the time between inception, implementation and completion (Young et al., 2014b). Owners and champions within council and amongst the councillors also need to be identified and brought on the journey.

6. Towards a framework

A framework for green infrastructure at the local government scale that aims to build resilience to climate change will need to promote the following attributes:

1. Resilience
    - Green infrastructure needs to be resilient. Because the urban form tends to accentuate climatic extremes, green infrastructure needs to be resilient to extremes of hot and cold, wet and dry, and rapidly changing conditions.
    - By lessening these extremes, GI will provide resilience for the surrounding built infrastructure, reducing damages and wear where possible.
    - GI can confer resilience on the community and business by providing places where people meet and interact, increasing physical and social connectivity, and strengthening community bonds and values.
    - The economic framework itself needs be adaptable in order to manage the different types of projects and contexts in which green infrastructure will be planned and implemented.
2. Risk reduction
    - Climate impact risk reduction contributes to resilience, but is purposely designed to provide specific services that lessen the physical, emotional and financial cost of damaging events.
    - Key risks identified in the urban environment are flash flooding, coastal flooding, drought, extreme heat, and windy and exposed environments. GI can be designed to reduce the impact of all these risks and/or to speed recovery from damage and loss.
3. Liveability
    - Urban environments are not always comfortable places. Grey infrastructure is built to be resistant, and buildings are often constructed with a carefully thought out interior designed for comfort but not so much the exterior. GI can be sued to soften these effects.
    - Improved walkability through provision of shelter.
    - General urban cooling in summer, reduce exposure in winter (if well designed).
    - Services that support individual and community health and wellbeing.
    - Spaces for gatherings, meetings and outings.

Three levels of benefit need to be built into the framework, namely:
1. Individual – benefits that contribute to personal welfare.
2. Community – benefits that accrue to community welfare.
3. Institutional – benefits that fulfil institutional goals and values.

These benefits overlap but use different measures of value. Individual benefits are income and level of satisfaction. Community benefits are collective social returns and connectedness. Feedbacks into the economy can either be positive or negative. Institutional values are used to both support individuals and communities. Institutions are key governors of a wide range of intangible values, so have a stake in green infrastructure benefits. While local government and the community are institutions, other institutions from state government, public corporations and industry also have a stake in benefits.

The framework will also seek to embed the development and operation of green infrastructure projects into local government and, as much as possible, state government. This will be carried out by identifying where current informal methods can be adapted and formalised, and by modifying methods and processes used for grey infrastructure to suit the specific needs of green infrastructure. Because single-point financing for GI is limited, a better understanding of how benefits are distributed can also help identify opportunities for strategic partnership development and co-funding.

The following principles based on both science and economics will be applied in developing the framework. They are as follows:

- The distribution and allocation of benefits is important. Some benefits a council has direct responsibility for, has a stewardship role in managing or are important downstream and upstream values in terms of environmental processes. Other benefits may be private or contribute to policies of other government bodies.
- The conservation of mass, function and character is assumed in that economic demand cannot produce goods and services that are unavailable due to physical or institutional restrictions. Irreplaceable aspects of GI need to be identified (within human timelines rather than evolutionary).
- Many ecosystem goods and services produced by GI need to be quantified on a scientific basis to ensure values are adequately represented.
- Monetary values should only be attributed to goods and services that have a market value, have a clear shadow price value or are accepted as standard practice in the area of operation. Further research will be required to develop areas of value that do not meet these criteria.

Conclusion

This green paper discusses the economic issues surrounding green infrastructure in order to develop a set of robust findings that can be used to inform a framework for valuing green infrastructure at the local government scale. This will utilise two other pieces of work: a review of the ecosystem services literature (Symons et al., 2014), the source of the ecosystem services listed in Appendix A, and learnings from a set of workshops that explored the decision-making processes surrounding green infrastructure in local government (Young et al., 2014a; Young et al., 2014b).

Many of the issues discussed in this paper are difficult to operationalise so where possible, they will have to be simplified so they are clear and straightforward to apply. However, some areas will remain ambiguous or continue to be contested within the literature or in policy circles. Where these cannot be easily incorporated into the framework, this paper will stand as a record of those issues.

The approach to economic issues applied here has been philosophical, focusing on identifying and allocating value, rather than positivist, focusing on achieving good outcomes through economic efficiency. Current methods for valuing social and environmental public good in Australia discount the future too rapidly and are out of step with best practice internationally. Those methods have not been applied and tested with green infrastructure, but discount environmental benefits at a faster rate than any ecologist would be comfortable with.

Delivering programs and projects that deliver and enhance community and environmental values in a cost-effective way are core institutional values for local government, in a similar way that cost efficiency is a core institutional value for other levels of government. There is also a strong thread in the ecological economics field that cost and engineering efficiency are incompatible with the economics of building resilient systems (Holling and Gunderson, 2002; Lebel et al., 2006; Potts, 2009). Combining these threads to support good decision making is the goal we have pursued here.

Appendix 1 Glossary

Deep ecology: Deep ecology is a philosophical position that attributes intrinsic value to the natural world, places humans within this and suggests humans have no right to exploit this for more than basic needs.

Discount rate: the interest rate used to bring future values into the present.

Discount rate (social): the discount rate used in computing the value of funds spent on social projects.

Ecomimicry: The application of technology to mimic ecological forms or functions.

Economics: the social science that seeks to describe the factors which determine the production and consumption of goods and services.

> **Classical economics**: Economic theory based on the supply of capital (land, labour) as the means of production.
>
> **Ecological economics**: Assesses ecosystem goods and services for their contribution to human welfare and in their own right. Treats the economy as being nested within the global environment with limited exchange between the two.
>
> **Environmental economics**: Assesses the impact of environmental policies and the role of the environment in the economy, especially where market failure leads to environmental degradation. Sees the natural environment in exchange with the conventional economy to maximise human welfare and focuses on marginal costs and benefits as opposed to absolute values.
>
> **Heterodox economic approach**: Application of economic methods without recourse to one particular orthodox position.
>
> **Monetary economy**: The part of the economy where goods and services are traded for money, and assets are sold in the marketplace. The market/non-market economy is delineated according to barter and trade.
>
> **Neoclassical economics**: Economic theory based on rational choice of the individual based on price, supply and demand. Neoclassical economics is based on marginal value and the maximisation of utility.
>
> **Non-monetary economy**: The part of the economy where goods and services are provided without monetary exchange (e.g., household labour, volunteerism, ecosystem services). Assets are generally (though not always) publicly owned.
>
> **Normative economics**: expresses value or normative judgments about economic fairness or what the outcome of the economy or goals of public policy ought to be. Economics distinguishes between normative economics ("what ought to be") from positivist economics ("what is").
>
> **Physical economy**: Stocks and flows in the material world, often simulated using input-output tables of material flows.
>
> **Polycentric economic approach**: Economic methods and approaches to a multi-layered system where “many elements are capable of making mutual adjustments for ordering their relationships with one another within a general system of rules where each element acts independently of other elements.”

Positivist (economics): Prescriptive methods that are held to produce good outcomes. Scientific/logical facts are held to be superior to values, which are subjective (origin in philosophy, but the fact/value distinction is now discredited).

Incommensurable: Kinds of value that are not considered to be interchangeable according to moral or philosophical reasoning, or with different units of measurement.

Net present value (NPV): the sum of the present values (PVs) of incoming and outgoing cash flows over a period of time. Incoming and outgoing cash flows can also be described as benefit and cost cash flows, respectively. Cash flows are converted into present values using a discount rate.

Sustainability (strong): Assumes that many aspects of natural capital and the services it provides cannot be substituted or compensated by money and that natural and manufactured capital are complementary but not interchangeable.

Sustainability (weak): Assumes substitutability between natural and manufactured capital and that environmental degradation can be compensated by payments from the monetary economy.

Utility: The use benefit of a measure, originally couched in terms of pleasure or satisfaction but now seen to be a measure of human welfare. In economics, one form of utility is often considered exchangeable with another, whereas if they are not, they are said to be incommensurable.

Values: The worth of a thing but also the different things themselves.

Anthropocentric value: Confers intrinsic value on humans alone and instrumental values on everything else.

Bequest/vicarious values: A willingness to pay to preserve the environment for the benefit of other people, intra- and inter-generationally.

Community value: A value shared by or benefiting a group of people who constitute a community through place, activity, or shared aspirations and goals.

Economic value: The worth of a good or service, or the measure of benefit provided by that good or service. Economic value is not just monetary, and there are many definitions across different economic traditions, from financial to philosophical.

Existence value: The value attached to the knowledge that species, natural environments and other ecosystem services exist, even if the individual does not contemplate ever making active use of them.

Institutional value: Value held by an institution as a guiding principle and/or goal.

Intangible value: Non-monetary goods, services, assets and intrinsic values.

Intrinsic value: The value attached to the environment and life forms for their own sake irrespective of any reference to humans.

Market value: The exchange value or price of a commodity or service in the open market. Sometimes also synonymous with economic value in neoclassical economics.

Non-anthropocentric value: Intrinsic value is attributed to human and non-human beings, and perhaps natural systems.

Option value: A willingness to pay a certain sum today for the future use of an asset.

Quasi-option value: The value of preserving options for future use assuming an expectation of increasing knowledge about the functioning of the natural environment.

Present value: The value today of a future asset, calculated into present day values (i.e., today's dollar value) using a discount rate

Tangible value: The monetary or market values of a good, service or asset.

Use value: The equivalent value of a good or service that is not or partially paid for translated into market-equivalent value.

Appendix 2

Areas and types of green infrastructure benefits (Symons et al., 2015)

Area of Benefit	Type of Benefit
Social	
i) Human health and well-being	
(a) Physical	• It can increase opportunities and reduce barriers to physical activity.[1] • It can influence travel behaviour, including the levels of walking, cycling, public transport and car travel.[2] • It can increase opportunities for recreational activity, by providing useable open spaces, as well as streets conducive to walking and cycling.[3]
(b) Social and psychological	• Activities in green settings can reduce children's Attention Deficit-Hyperactivity Disorder symptoms.[4] • Children who live in apartments with greener, more natural views scored better on tests of self-discipline than those living in more barren settings.[5] • Women who live in apartment buildings with trees and greenery immediately outside reported greater effectiveness in dealing with their major life issues than those in more barren settings.[6] • Dramatically fewer occurrences of crime have been observed against both people and property in apartment buildings surrounded by trees and greenery than in nearby identical apartments that were surrounded by barren land.[7] • Green Infrastructure can also be incorporated into medical institutions for therapeutic purposes where patients recover faster.[8]
(c) Community	• Residential common areas with trees and other greenery help build strong neighbourhoods.[9] • Urban amenity, including the role of Green Infrastructure in creating more 'walkable' streets and more 'liveable' cities by enhancing human comfort, safety and enjoyment.[10] • The specific liveability benefits of air quality improvement and noise abatement in cities.[11]
ii) Cultural and spiritual	• Cultural values, including community heritage values and the deeper symbolic and other values of urban nature.[12]
iii) Visual and aesthetic	• The visual and aesthetic role of Green Infrastructure contributes to the attractiveness of urban streets, neighbourhoods and city centres.[13]

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[2] Frumkin, H., L. Frank and R. Jackson, 2004: *Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities*. Island Press, Washington, DC, 368 pp.

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[12] Konijnendijk, C.C., 2008: *The Forest and the City: The Cultural Landscape of Urban Woodland*. Springer Netherlands, Dordrecht, 246 pp.

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2)	Economic		
	i)	**Commercial vitality**	• Consumers show a preference for shopping areas with trees, which also influenced customer perceptions of businesses and their products. Survey respondents indicated they would travel further, visit more often and spend more.[14]
	ii)	**Increased property values**	• Many studies have shown the presence of trees has been found to increase the selling price of a residential property.[15]
	iii)	**Value of ecosystem services**	• Research in the US 'Measuring the Economic Value of a City Park System' identified two factors that parks provide a city with direct income: 1. Increased rates and property tax from the increase in property value due to the proximity to parks. 2. Increased sales tax on spending by tourists who visit an area primarily due to the parks. • Three other factors lead to direct savings: 1. Residents' free use of parkland and other free or low-cost recreation opportunities (rather than having to purchase these in the marketplace) is the largest. 2. Health savings in medical costs due to the benefits of increased physical activity in parks comes second. 3. Community cohesion benefit of communities 'coming together' to save or improve local parks has been shown to reduce antisocial problems that may otherwise cost the city more in policing and rehabilitation. • The last two factors provide environmental savings, including water pollution reduction through stormwater retention via the park system's trees, vegetation and soil, reducing treating stormwater control and treatment costs. Air pollution is also reduced by park's trees and vegetation.[16]
3)	Environmental		
	i)	**Climatic modification**	
		(a) Temperature reduction	• Trees and vegetation can improve local microclimate and help reduce the 'urban heat island effect'. These climatic benefits provided by trees and vegetation include: • Improving human comfort for street users. • Modifying local microclimates. • Reducing the urban heat island effect. • Providing health benefits especially for the aged. • Reducing energy use and carbon emissions.[17] • Assisting in climate change mitigation and adaptation.
		(b) Shading	• Tree shading decreases local temperature and improves comfort. By applying the effects of tree shade on the eastern and western sides of a Brisbane single story three star energy rating home to the Building Energy Rating System model, energy savings of up to 50% per year could be achieved.[18]
		(c) Evapotranspiration	• Trees provide additional cooling through evapotranspiration which absorbs heat in the process of evaporating water in the plant.[19]
		(d) Wind speed modification	• A barrier of approximately 35 percent transparent material can create a long calm zone that can extend up to 30 times the windbreak height.[20]
	ii)	**Climate change mitigation**	
		(a) Carbon sequestration and storage	• As about 50% of wood by dry weight is comprised of carbon, tree stems and roots act to store up carbon for decades or even centuries. Over the lifetime of a tree, several tons of atmospheric carbon dioxide can be absorbed.[21]

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[21] McPherson, B. and E. Sundquist, 2009: *Carbon Sequestration and Its Role in the Global Carbon Cycle*. American Geophysical Union, Washington DC, 183 pp.

	(b) Avoided emissions (reduced energy use)	• Avoided CO_2 emissions due to reduced energy use and the associated reduction in carbon dioxide emissions from fossil-fuel based power plants[22]
iii)	**Air quality improvement**	
	(a) Pollutant removal	• Trees absorb gaseous pollutants through the leaf surface (SO_2, NO_2) as well as intercepting particulate matter on leaves (PM10 and PM2.5).[23]
	(b) Avoided emissions	• Indirectly, by reducing air-conditioning use and related energy consumption in buildings (through shading of buildings, air temperature reduction and wind modification) leading to lower air pollutant emissions from power plants (known as avoided emissions).[24]
iv)	**Water cycle modification**	
	(a) Flow control and flood reduction	• Urban stormwater harvesting raises the possibility of increasing urban water supply and improving water quality in riparian environments and receiving water. In addition, benefits from stormwater harvesting including reduced heat stress, improved balance between high and low flows in water ways, improved amenity of the landscape.[25]
	(b) Canopy interception	• Canopy interception is the rainfall that is intercepted by the canopy of a tree and successively evaporates from the leaves.
	(c) Soil infiltration and storage	• Biofiltration systems are an important component in improving the quality of urban stormwater runoff, and protecting aquatic ecosystems. Vegetation is the key factor in biofiltration systems as it increases the pollutant removal function of the soil through a combination of physical, chemical and biological processes.[26]
	(d) Water quality improvement	• Biofiltration improves water quality through the removal of pollutants.[27]
v)	**Soil improvements**	
	(a) Soil stabilization	• Greater amounts of vegetation increase soil stability and decrease soil erosion and loss.[28]
	(b) Increased permeability **(c) Waste decomposition and nutrient cycling**	• Porous and permeable surfaces paving can play a role in water quality through pollutant removal from stormwater runoff, by assisting in biological decomposition of contaminants.[29]
vi)	**Biodiversity**	
	(a) Species diversity	• Increased and differing habitats lead to increased species diversity.[30]
	(b) Habitat and corridors	• Wider benefit to the local area through biodiversity and habitat provision.[31]
vii)	**Food production**	

[22] Donovan, G. and D. Butry, 2009: The value of shade: Estimating the effect of urban trees on summertime electricity use. *Energy and Buildings*, **41**, 662-668.
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(a) Productive agricultural land	•	Agricultural and other productive land, including vineyards, market gardens, orchards and farm.[32]
(b) Urban agriculture	•	Urban agriculture incorporates productive land on the peri-urban boundary to provide more sustainable food sources for urban areas. It also includes community gardens, kitchen gardens and 'edible landscapes'.[33]

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