Sustainable Infrastructure Guidelines

Produced and maintained by the

Local Government Infrastructure Design Association

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Victorian Local Sustainability Accord
Sustainability Fund
Victoria
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sustainable infrastructure guidelines

These Guidelines have been prepared as a result of a funding grant from the Victorian Local Sustainability Accord. A key initiative of the Accord is the Victorian Local Sustainability Advisory Committee (VLSAC).

A large number of sustainability challenges face local governments, many of which will be amplified by the changing climate. Based on input from the Accord partners and extensive consultation with local governments across Victoria, the VLSAC has identified five key issues for priority action over the next phase of the Accord. These are complex, cross-jurisdictional issues that require action at both the State and local government level to facilitate sustainability outcomes for local communities and Victoria as a whole.

1. Planning issues
2. Building distributed energy and other systems
3. Sustainable local economies
4. Social impacts of climate change
5. Managing carbon emissions

In addition to these priorities, the VLSAC and the Accord will continue to be responsive to and support other key issues identified by local governments through their environmental planning processes. Such issues might include biodiversity loss, protecting urban landscapes, sustainable public lighting and managing sustainability data. These, and other issues, will be considered by the VLSAC as the areas for action emerge, allowing the VLSAC to be flexible to meet the needs of the sector.

These Guidelines seek to provide guidance on alternative design considerations and materials that will deliver more sustainable infrastructure through:

- Using recycled materials
- Reducing the carbon footprint of infrastructure projects
- Reducing maintenance and operating costs
- Utilising water in more efficient ways
- Utilising materials from sustainable sources

Existing design standards in the IDM have been developed over time based on generally accepted principles and practices, including those applied to member Councils and other jurisdictions. These standards provide effective and workable solutions for the provision of municipal infrastructure and while it is recognised that to move to more sustainable solutions requires significant change, there is no intention to apply a reduction in the design standards contained in the manual.

The Guidelines address a number of initiatives contained in the Accord's Sustainability Action Statement including – healthy and productive land and water systems, flourishing biodiversity, less waste and increased resource efficiency, communities with a water, energy, materials saving ethic, liveable cities and towns and efficient transport systems.

This project was funded through the Victorian Government's Sustainability Fund under the Victorian Local Sustainability Accord.

The City of Greater Geelong and the Colac Otway Shire were the lead agencies on behalf of the IDM Group for the funding grant. The project was administered by the City of Greater Geelong.

TABLE OF CONTENTS

Clause 1 Introduction

1.1 Sustainable Design

Sustainability can be defined as meeting the economic social and environmental needs of current generations without compromising the needs of future generations. Accordingly, more sustainable infrastructure should require less energy and natural resources to build, operate and maintain, generate less pollution and preserve the natural environment to the greatest extent possible. Where there is a loss of natural resources these should be replaced or replenished. Sustainable design of infrastructure based on the principles of "reduce, reuse and recycle" will require greater community awareness of its objectives and benefits, and of how sustainable infrastructure works and is maintained. For example, the community will have to take a greater interest in, and ownership of, assets such as water-sensitive design elements

Sustainable infrastructure is based on site layouts that are more compact, provide increased transport choices, reduce water consumption and protect natural streams and watercourses.

Sustainable development is a continually evolving and expanding field both in the approach to design (and challenges to the status-quo) and in the emergence of new materials. In implementing sustainable development there will be resistance to change, need for policy change and limitations imposed by current regulations.

1.2 Consultation

This Sustainable Infrastructure Guidelines has been prepared by conducting research on design practices and materials in Australia and overseas reflecting concepts such as Green Infrastructure, Sustainable Development and Low Impact Development. Consultation has been carried out with:

- CCF (Civil Contractors Federation)
- Local Government Victoria (LGV)
- Australian Asphalt Pavement Association (AAPA)
- VicRoads
- Association of Land Development Engineers (ALDE)

1.3 Implementation

1.3.1 Innovation and Advances in Technology

Clause 1.9 of the Infrastructure Design Manual provides a mechanism through which Councils may consider adopting and approving innovative solutions and using new technologies where they are satisfied that the objectives of the relevant clauses of the IDM will be achieved although the proposal may not comply with all relevant technical provisions.

1.3.2 Development Plans (DP)

Development Plans should be submitted for review with a written response to the provisions in the Planning Scheme (for residential Developments), guidelines contained within the IDM and these Guidelines where required by a Council listed in Selection Table 3.6.1 in Clause 3.6 of the IDM. Councils will expect consideration also to be given to the 'Safer Design Guidelines for Victoria' published by DSE, the VicRoads brochure 'Safer Urban Environments – Road Safety and Land Use Planning Guide' and any 'Healthy Urban Design Guidelines' developed by Councils.

1.3.3 Sustainable Infrastructure Checklist

A Sustainability Checklist is provided in Appendix B of these Guidelines to provide documentation to demonstrate that the objectives of the Guidelines have been considered and implemented to assist Councils to assess the sustainability of a development... Councils listed in Selection Table 3.5 in Clause 3.5 of the IDM will expect the checklist to be completed for all significant developments within their municipal boundaries.

The intention and benefits of the checklist are:

- To support the vision, goals and actions of the individual Councils in relation to their Greenhouse Action Plans, Environment Strategies, Capacity Building and Climate Resilient Communities
- To encourage more sustainable infrastructure design
- To provide a consistent "sustainability-focused" review of Development Applications.
- To raise industry awareness of the benefits of applying sustainable best management practices
- To document how and to what extent new developments are incorporating sustainable design and technology
- To help developers to evaluate the sustainability of their projects

1.4 Objectives

The objectives of the Sustainable Infrastructure Guidelines are:

- To provide a range of sustainable design options and materials that reduce the carbon footprint of infrastructure projects recognising that some options can be adopted immediately, some may be more suitable in urban environments than rural and others may be more aspirational in nature, and may require regulatory or policy change or innovation in order to be delivered
- To provide infrastructure in a way that preserves the natural environment, protects habitat and maintains or increases biodiversity
- To provide infrastructure that uses stormwater more efficiently by reducing peak volumes and increasing the volume that is retained in water sensitive design elements prior to discharge to watercourses
- To better integrate design elements such as road, landscape and stormwater conveyance to increase sustainability and meet amenity, accessibility and level of service provisions while delivering greater aesthetics
- To introduce processes and rating tools by which projects can be evaluated on sustainability criteria and improved
- To increase confidence levels in the use of alternative designs and materials
- To encourage broader thinking around sustainability initiatives at the design stage

Clause 2 Definitions

Carbon Footprint	The amount of carbon dioxide and other greenhouse gases emitted into the atmosphere from infrastructure activities. This includes all emissions associated with materials (extraction, manufacture and transport), construction, and maintenance over the lifecycle of the relevant infrastructure.
Geopolymer cement	Made from mixtures of water-soluble alkali metal silicates and aluminosilicate mineral powders such as fly ash. Essentially Geopolymer cement is seen as a replacement for Portland cement.
Low Impact Development	Similar to the term Water Sensitive Urban Design (WSUD), Low Impact Development (LID) puts an emphasis on conservation and use of on-site natural features to protect water quality through the implementation of hydrologic controls in an attempt to replicate the pre-development and even pre-settlement hydrologic regime.
Permeable Pavement	A pavement with a permeable surface is constructed over a drainage or storage layer promoting ground water recharge, reduction of traditional stormwater conveyance infrastructure, and pollutant storage/ and biodegradation. These pavements are mostly suitable for lightly trafficked areas such as carparks and parking bays.
Reinforced Turf	Typically concrete or plastic grids that are filled with topsoil and grassed to provide a surface that can support traffic loads without compacting or damaging the underlying soil.
SIG	Sustainable Infrastructure Guidelines
Structural Soil	Typically large single sized aggregate with the voids filled with topsoil. The aggregate provides structural support while preventing compaction and the voids allow root growth with minimal displacement of the aggregate.
Sustainable	Meeting the economic social and environmental needs of current generations without compromising the needs of future generations
Sustainable Development	The World Commission on Environment and Development (WCOED) defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

Clause 3 Design Requirements

3.1 Objectives

The objectives of this clause are:

- To identify how sustainable variations from the design requirements specified in the IDM can be evaluated.
- To describe available rating tools that can be used to assess project sustainability
- To promote the use of the Sustainable Infrastructure Checklist (Appendix B) as a mechanism for encouraging wider adoption of sustainable infrastructure

3.2 Design Considerations

Sustainable design initiatives are described in more detail in the relevant clauses of the SIG. When an innovative design solution is proposed that does not meet all the engineering standards required by the IDM, Councils will expect the following factors are to be assessed and documented by the Designer prior to submitting a request for approval:

- Life-cycle costs
- Carbon footprint of the proposal compared with a conventional design
- Environmental and ecological benefits including, but not limited to, reduction in impervious surfaces, reduction in pollution, protection or enhancement of biodiversity, improvement to water quality, reduction in waste, and increase in utility
- Impact on the future operation, maintenance and renewal of the proposed infrastructure

The treatment of waste and surplus material associated with earthworks is often overlooked in design, with materials being sent to landfill when they may be suitable for reuse. Clause 6 of the SIG identifies particular initiatives that can be implemented to treat such materials in a more sustainable manner.

3.3 Variations from Design Guidelines

3.3.1 General

The SIG provide detail on innovative solutions and new technologies that can be considered by Design Engineers and Developers seeking to create more sustainable infrastructure.

Clause 5.7 of the IDM specifies that any proposal to deviate from the Manual guidelines at any stage of the works should be submitted with full supporting reasons to, and be approved in writing by, Council prior to the commencement of the relevant work. In addition, IDM Clause 3.5 provides that, where the Design Engineer can demonstrate that proposed variations from the Manual are consistent with the SIG, Councils listed in Selection Table 3.5 of Clause 3.5 of the IDM as having adopted the SIG will normally accept that the objectives of the relevant IDM clauses have been met, although the proposal may not comply with all relevant technical provisions. Sustainable initiatives need to be evaluated on their merits for each development and variations which have been approved for some developments do not imply approval for other current or future proposals. Consequently, the implementation of sustainable options outlined in the SIG should be considered on a project by project basis as part of the design process. The rating tools identified in Section 3.5 of the SIG will often be helpful when comparing the relative merits of the available options in any particular circumstances.

3.3.2 Owners Corporations

Owners corporations provide one way in which alternative designs, particularly with respect to layout of housing estates and communities, can be implemented. Infrastructure within the common property can be designed with greater flexibility and will not be subject to all the standards that would apply to infrastructure that is ultimately owned and managed by

Council. An owners corporation may also be more informed about the purpose and operation of water-sensitive design features, and more committed to their effective management and maintenance.

3.4 Documents to be submitted

Clauses 5.2 and 5.8 of the IDM, specify that, unless otherwise agreed by Council, engineering plans and documentation should be submitted at three separate stages during the design process. More sustainable design or material options being considered by the Design Engineer should be highlighted in the designs, specifications, calculations, relevant drawings and other documents that accompany the submission.

3.5 Rating Tools

Rating tools provide a framework for systematically assessing projects sustainability by:

- Evaluating the project against a wide range of sustainability criteria
- Benchmarking the project against similar successful projects in other jurisdictions
- Enabling designers and asset owners to identify areas where improvements can be made

Available rating tools include:

- Infrastructure Sustainability Scorecard – published by the Infrastructure Sustainability Council of Australia (www.isca.org.au). This tool can be used to assess most types of infrastructure including transport, water, communication and energy
- Greenstar Rating Tools – published by Green Building Council Australia (www.gbca.org.au). These tools are primarily used for building projects, but also include a Communities rating system that can be used for precincts, towns and cities
- Greenroads™ Rating System – published by the University of Washington (www.greenroads.org). This rating tool was designed primarily to rank, score and compare the sustainability different major road projects but may sometimes be useful in dealing with other civil infrastructure
- Invest – Sustainable Highways Self Evaluation Tool published by U.S. Department of Transportation Federal Highway Administration (www.sustainablehighways.org)

3.6 Materials

The sustainability of various construction materials can be assessed and compared against core and supplementary indicators by reference to Clause 9 of the SIG and the Material Information Sheets in Appendix A.

Appendix C provides a carbon calculation tool for estimating the embodied carbon per unit of the construction materials that have been assessed in Clause 9 of the SIG. The tool can be used to determine overall amounts of embodied carbon for typical infrastructure items and aggregated up to project level based on the quantities of individual materials.

Clause 4 Transport

4.1 Objectives

More sustainable road design and construction can reduce use of fossil fuels, reduce water consumption, greenhouse gas emissions, water pollution, and life-cycle costs, facilitate restoration and/or creation of habitat, improve access and mobility, generate local economic benefits, and raise community awareness. The objectives of sustainable road design are to:

- Provide an efficient road network that safely moves people in a variety of transport modes including vehicles, walking, cycling and public transport while minimising impact on surrounding environment
- Develop layouts that allow for access in all directions, link to public transport, reduce dependence on cars and provide walkways and cycleways that are continuous and linked to each other
- Consider interactions between land use and transport recognising that compact communities that have a range of transport options place less demand on the existing road network
- Introduce a variety of landscaping and traffic calming techniques, particularly for residential and local roads, that create safer roads which promote social interaction and provide additional visible green space
- Reduce the overall requirements for car parking and particularly those for areas with a hard footprint, and ensure that parking spaces are so located as to avoid adverse impacts on cycling and walking options.

4.2 General

In low speed environments, the road hierarchy should reflect the nature of the intended users as follows:

- Pedestrians
- Cyclists
- Public Transport
- Other road users

New development should aim for preferred rather than absolute minimum standards with respect to pedestrian, cycle and public transport facility provision.

The benefits of these active transport modes include:

- Reduced transport related emissions
- Reducing car parking demand
- Improved liveability in residential areas
- Improved health through increased physical activity

Ensuring that cycle links between new and existing development are provided and that local area traffic management is cycle friendly in design help to promote cycling as a viable traffic mode. Typical steps that may be considered include providing cycle cut-throughs at road narrowing features, speed humps and other traffic calming measures.

In residential precincts, consideration should be given to imposing lower speed limits (10kph/20kph) and giving pedestrians and /cyclists priority over motor vehicles

4.3 Road Location and Layout

The following factors should be considered in determining road layouts:

- The design should occupy the smallest possible footprint
- Natural vegetation should be retained wherever possible and supplemented with additional landscaping
- Disturbance of natural soils should be minimised
- Road design and layout should aim to maximise areas of the road reserve and adjacent land that can be utilised for offset planting or otherwise upgraded to restore habitat lost as a result of the proposed road
- Where possible impervious areas should be disconnected from each other and water flow directed to pervious areas
- Natural buffers and vegetated areas should be interconnected
- Crossing points with protective and directive fencing can minimise conflict between native animals and vehicles
- Significant slopes should be protected with carefully designed and selected vegetation
- So far as reasonably practicable, having regard to access needs for emergency and service vehicles, roads in residential precincts should encourage compliance with the design speed limits by lateral and vertical geometry, rather than traditional traffic calming devices. When such devices are unavoidable, raised pedestrian crossings, pavement narrowing, kerb radius reduction and raised medians can be considered, and may offer opportunities for increased landscaping
- So far as reasonably practicable, indented parking bays should be preferred to continuous parking lanes, since they create opportunities for the use of permeable pavement (see Section 4.7 of the SIG)
- Cul–de-sacs can discourage alternative modes of travel, blocking direct pathways for pedestrians and cyclists, limiting access for public transport, and requiring additional paved areas (which can be reduced by providing a central landscaped island).
- Designs should follow Safe System Principles. Austroads AP-R560-18- *Towards Safe System Infrastructure A Compendium of Current Knowledge* summarises current Safe System knowledge and research in regard to planning, designing and managing roads and advises roads “should be planned,designed and operated to be forgiving of inevitable human errors so that severe injury outcomes are unliklely to occur”.

4.4 Footpaths

The IDM requirements for footpath provision have been designed to maximise the options for service location within the framework of the Code of Practice for Management of Infrastructure in Road Reserves and to provide a safe environment for pedestrians, including those with limited mobility. In certain cases, substitution of a shared path for a footpath may be acceptable. Consideration may be given to using permeable pavement for footpaths.

4.5 Cycleways

The function of cycleways is to transport users from destination to destination and a given cycleway is likely to include a route that involving a combination of on street and off street travel.

The safety and convenience of cyclists and pedestrians within the general traffic system is usually achieved by segregation from vehicular traffic, in time and/or space. This may be achieved by separate lanes and paths, signalised crossing points and other treatments. Local streets should be attractive and feasible for cyclist movement, with an expectation that different road users will share the street space, as discussed in the Austroads *Guide to Traffic Management Part 8: Local Area Traffic Management* and Guide to Traffic Management Part 7 *Traffic Management in Activity Centres.*

Safe and convenient cycling facilities benefit those who already cycle and encourage greater participation in cycling by those who do not. Cycling facilities are to be considered at the planning phase and incorporated into the design process so that potential conflicts with other modes and terrain or right-of-way constraints are adequately resolved. Cycleways risk being under-designed if they are considered add-on features.

Adequate parking and security provisions need to be provided at destinations. The Austroads publication *Cycling Aspects of Austroads Guide*s provides comprehensive information on the planning, design and traffic management of cycling facilities.

4.6 Carparks

The following strategies should be considered, noting that not all of them may meet current Planning Scheme provisions:

- Reduce minimum car parking rates where there is a demonstrated commitment to bicycle infrastructure, beyond that required in the IDM
- Reduce minimum car parking rates for multi-use sites where the demonstrated peak demand is less than the statutory parking rate for the combined uses
- Separate street parking from pedestrian and cycle paths
- Consider car-sharing and sustainable travel plan initiatives including, but not limited to, providing:
  - up-to-date information on all public transport modes stopping near the workplace
  - secure parking for cycles and motorcycles
  - changing facilities and lockers for cyclists
  - company bicycle pools for short-distance work-based trips
  - car-sharing services, with involvement from local businesses where appropriate
  - preferential parking spots for those engaged in car-sharing
  - company car pools for work-based trips
  - appropriate incentives, such as walk/cycle to work days
  - subsidies to public transport services
- Treat vehicle overhang spaces with gravel or planting to reduce hard surfaces
- Provide small parking bays (and car stackers in appropriate developments)
- Provide car-sharing spaces in sufficiently high density environments
- Provide overflow parking spaces with permeable surfaces in areas subject to infrequent heavy use.

4.7 Permeable Pavements

4.7.1 General

Permeable pavements allow rainwater to pass through the surface and be temporarily stored in a drainage layer that forms part of the structural pavement. They can help to reduce the peak flow and total volume of runoff, improve water quality by removing pollutants, and allow greater infiltration into the subsoil. Consideration should be given to replacing impervious surfaces with permeable alternatives in appropriate circumstances.

Types of permeable pavement include:

- Open graded asphalt
- No fines concrete
- Permeable pavers – interlocking pavers with a series of enlarged joints between pavers that provide the majority of the porous surface
- Reinforced turf – typically concrete or plastic grids that are filled with topsoil and grassed to provide a surface able to support traffic loads without compacting or damaging the underlying soil
- Structural soil – typically large single sized aggregate with voids filled with topsoil. The aggregate provides structural support whilst preventing compaction and the voids allow root growth with minimal displacement of the aggregate
- Resin bound paving – aggregate (typically 3mm to 10mm in size) bonded with resin. Crushed glass can also be substituted for rock-based aggregate

These types of pavement are suitable for lightly-trafficked areas such as carparks and parking bays. The design approach differs from that applied to conventional flexible pavements. Typically a permeable surface, such as open-graded asphalt, no-fines concrete, permeable pavers, or reinforced turf, is constructed over a drainage and/or storage layer comprising uniformly-sized aggregate. The surface layer and drainage layer can temporarily store stormwater, allowing it to infiltrate into the subgrade through the sides and bottom of the pavement with only the residue being drained into a conventional or water-sensitive stormwater conveyance system. Permeable pavements require special designs, including assessment of infiltration rates.

The advantages of permeable pavements include:

- Ground water recharge
- Reduced need for traditional stormwater conveyance infrastructure
- Storage and biodegradation of pollutants

The disadvantages include:

- Blockage by sediments and/or other pollutants
- Need for more frequent replacement than equivalent impermeable pavements
- Need to be installed down slope from building foundations unless specific drainage provisions are implemented

Permeable pavements should normally be designed with an overflow system to ensure that the system remains functional in the event that the drainage medium becomes clogged.

4.7.2 Permeable Pavement Design

The design procedure for permeable pavements must consider both stormwater management and structural performance, and will often involve some compromise.

For stormwater management, the design software package PERMPAVE (Concrete Masonry Association of Australia) is available, and can also be used to undertake water quality and harvesting/reuse analysis.

For structural design, normal mechanistic methods should be used. Several appropriate software packages are available, including DesignPave (Concrete Masonry Association of Australia) and CIRCLY (Mincad Systems Pty.Ltd.).

Design Engineers can refer to ARRB report *Design of Permeable Pavements for Australian Conditions* which outlines a recommended methodology for designing permeable pavements in more detail. INTERPAVE (Precast Concrete Paving and Kerb Association U.K) also provides useful technical documents, including standard cross-sections for the design of permeable pavements.

4.8 Recycled Pavements

Recycled pavement in this context refers to the reuse of existing pavement material. This could include pavement that has been removed from another location or insitu pavement that is retained and added to (e.g. widening, overlay, resurfacing). Existing pavement material may meet required specifications or may need to be stabilised. Common stabilisation methods include mechanical, lime, cement and bitumen.

Where an existing pavement is being upgraded, the new finished surface levels should be set above the existing levels to the greatest extent possible commensurate with achieving required geometric standards. This approach maximises the amount of insitu pavement retained and derives the maximum strength from that pavement. Experience has shown that older pavements can actually lose strength when disturbed and recompacted.

4.9 Pavement Materials

4.9.1 Pavement Base and Sub base

Current alternatives to conventional crushed rock or natural gravel bases and sub bases include recycled crushed concrete which can be supplemented with varying amounts of crushed brick, clay filler, clayey sand or crusher fines, recycled asphalt pavement and crushed glass. VicRoads Standard Specification 820 – Crushed Concrete for Pavement Sub Base and Light Duty Base provides details of materials that can be substituted for conventional Class 2, 3 and 4 Crushed Rock. Materials complying with Specification 820 may also be used as bedding under footpaths, slabs and kerbs and may also be used as bedding and backfill for culverts.

VicRoads Technical Note TN 107 *Use of Recycled Materials for Road Construction* provides further information on availability and use of alternative pavement materials.

4.9.2 Pavement Wearing Course

Alternative pavement wearing courses include:

Warm Mix Asphalt

Warm mix asphalt is similar to conventional asphalt (hot mix) but produced at a lower temperature (typical range 120^{0}C-130^{0}C, compared with 160^{0}C-170^{0}C for conventional asphalt). To offset the lower temperature either a foaming process (where water is added to the bitumen) or a wax chemical additive is used to facilitate production. It is generally accepted that the performance of warm mix asphalt is equivalent to conventional hot mix..

The benefits of warm mix asphalt are:

- Improved safety due to lower production and handling temperature
- Longer working time and less performance loss in transit
- Requires less energy to produce
- Can incorporate higher percentages of RAP than conventional hot mix

There are no apparent disadvantages of warm mix asphalt compared to hot mix.

Recycled Asphalt Pavement (RAP)

RAP is asphalt that has been reclaimed from existing roads and then incorporated into new asphalt mixes. Current VicRoads Specifications allow between 10% and 40% of RAP to be included in new mixes depending on the particular mix type (Refer VicRoads Standard Specification 407). Recent research in Canada has confirmed that RAP can be used effectively within this range, subject to specific mix design when the proportion exceeds 20%.

Warm Mix Asphalt Incorporating a Percentage of RAP

A combination of warm mix asphalt combined with RAP provides even greater environmental benefits with no apparent loss of performance particularly under the lighter traffic volumes that apply to most Council roads.

Emulsion Seals

Emulsion binders can be used as an alternative to hot bitumen. They can be used all year round but are more suited for cool and or damp conditions. Austroads *Guide to Pavement Technology Part 4F: Bituminous Binders* states “Emulsions can be used in sprayed seals for many of the applications of hot bitumen. The advantages include less heating, reduced use of cutter oils in cool conditions and improved adhesion to damp surfaces in some circumstances. The disadvantages include a higher cost due to the cost of emulsification and a slower rate of strength gain that increases the time before seals can be trafficked, particularly in cooler conditions”.

4.10 Material Information Sheets

Conventional pavement materials and their sustainable alternatives can be compared by referring to the Material Information Sheets in Appendix A and associated guidelines in Clause 9.

Clause 5 Integrated Water Management

5.1 Objectives

Sustainability in drainage design for developments is principally concerned with protecting the environment from changes to the water regime of catchments, while minimising the resources required to construct drainage infrastructure and the carbon footprint of that infrastructure.

Drainage strategies and designs should:

- Protect water quality, catchments and watercourses from environmental damage
- Provide an efficient stormwater system that protects people and property from flooding
- Maximise the use of natural drainage paths to reduce the need for artificial floodways and drains
- Avoid unnecessary consumption of resources in the construction of drainage systems
- Minimise the carbon footprint of drainage infrastructure

5.1.1 Urban Drainage

The objectives of IDM Clause 16 *Urban Drainage* are to:

- collect and control all stormwater generated within the subdivision or development;
- collect and control all stormwater entering a subdivision from catchments outside the subdivision;
- provide an effective outlet for all collected stormwater to a natural watercourse or acceptable outfall; and
- achieve these objectives without detriment to the environment generally, surface and subsurface water quality, groundwater infiltration characteristics, adjoining landowners and landowners in the vicinity of the drainage outlet, and watercourses either upstream or downstream of the subdivision.

While these objectives focus on the collection, control and removal of stormwater from the development area; the principles of sustainable development impose an obligation to manage stormwater in a way that preserves or restores the natural environment as well as limiting the consumption of resources to sustainable levels.

In urban areas and growth areas on the urban fringe the natural environment will usually have been degraded by previous urban development and rural land uses. There may be an opportunity to both preserve and rehabilitate natural features.

5.1.2 Rural Drainage

The objectives of IDM Clause 17 *Rural Drainage* are to

- collect and control all stormwater generated in or transferred through the Development or subdivision and ensure that it is discharged from the site without detriment to any upstream or downstream property;
- ensure that any Developments or subdivisions that would otherwise increase the rate and quantity of stormwater runoff retard outflows to rural runoff rates where applicable;
- provide an effective outlet to an acceptable outfall;
- ensure that culverts and waterways are designed so the safe passage of vehicles is maintained at all times;
- restrict stormwater flows to natural drainage lines and avoid crossing drainage catchment boundaries;
- comply with the objectives and requirements of any relevant Floodplain Authority;

5.2 Introduction

The concept of sustainable development in water management extends to all aspects of land development. In modifying the existing landscape, any development modifies:

- The natural absorption and run-off characteristics of the land
- The demand for and distribution of water within the land
- The consumption of materials for construction
- The use of resources for on-going maintenance and operations

The Planning and Environment Act 1987 identifies its purpose as being *to provide a framework for planning the use, development and protection of land in Victoria in the present and long term interest of all Victorians*.

In urban areas of Australia water sensitive urban design (WSUD) has been introduced to achieve a more sustainable approach to water management. The Melbourne Water Guidelines for WSUD note that WSUD seeks to achieve integrated water management by:

- *Managing the demand for water by reducing it*
- *Assessing the appropriate potable or alternative supply of water for the end purpose*
- *Applying best practice to stormwater management*

These principles should be considered in all phases of planning and design.

5.3 Environmental Issues

5.3.1 Urban Drainage

Urban areas dramatically change the environment by deforestation and earthworks, by construction of impervious areas and by pollution. Any remaining natural elements are severely impacted and much natural flora and fauna has not survived this disturbance.

In the past, little effort was made to protect the natural water regime from adverse impacts or to maintain the balance of water in the local environment. Many natural catchments now have far less infiltration to groundwater and have correspondingly increased run-off and watercourses are often degraded by erosion, pollution and loss of habitat.

Where riparian vegetation has been removed or died, watercourses are subject to increased erosion and stormwater run-off becomes contaminated with silt and in varying degrees with nutrients, litter and traces of petroleum products and other chemicals. Gardens and recreation grounds have traditionally been irrigated with reticulated water that was prepared to potable water standard at considerable expense and input of energy and other resources.

This approach has not been a sustainable practice in terms of ecological balance or conservation of resources. The introduction of Water Sensitive Urban Design (WSUD) principles and practices has put stormwater design and management on a more sustainable footing.

Many natural watercourses in Victoria are ephemeral streams that only flow during and immediately after rainfall events. Such streams often have riparian vegetation that is supported by the ground moisture conditions under the watercourse and by occasional surface flows. These riparian corridors need to be protected by maintaining at least some of the natural water flow – the vegetation is a valuable part of the natural environment and protects the watercourse from erosion.

Perennial streams and rivers are sophisticated ecosystems that commonly experience a wide range of flow conditions in their natural state. Urban stormwater can significantly modify the natural conditions of flow and water quality.

Stormwater needs to be managed in a way that avoids increased erosion of stream beds and avoids unnatural silt loads and increased salinity. It also needs to be protected from discharges of chemicals, litter, petroleum products, sewage and other man-made pollution.

5.3.2 Rural Drainage

There are more opportunities for sustainable design in rural areas than urban areas because of the additional percentage of undeveloped space available to off-set the impacts of development on the water cycle.

Many watercourses in rural areas have been degraded by agricultural and forestry activities and additional run-off caused by land clearing. New developments can avoid or even reverse such damage if suitable stormwater retardation, treatment, storage and infiltration measures are put in place.

5.4 Climate Change

There is a widespread acceptance by the scientific community that global climate will change significantly this century, and that greenhouse gas emissions will have an important role in that process. The degree of that change will vary considerably between regions and current climate change modelling results have a wide confidence range. However, many climate scientists believe that extreme rainfall events will become more frequent, average annual rainfall will increase in some regions and decrease in others, and average temperatures and sea levels will increase significantly.

Given this measure of consensus, careful consideration should be given to the resilience of designs and materials. For example, more intense rainfall events may require larger pipes or culverts and/or improved provisions for collection and storage of stormwater. Materials with increased resilience to erosion may need to be chosen in situations where high flows cause solids movement upstream of the drainage pipes or culverts. Piped exit points to natural water bodies may need to have added protection against erosion.

Some predictions suggest that increased periods can be expected to elapse between major rainfall events, in which case, combined with higher temperatures, increased drying of soil and corresponding soil movement can be expected. Materials used for drainage and surfacing of open spaces should be chosen with this in mind. Additionally the bedding materials and/or depth of bedding may need to be altered to provide increased resilience of the finished structures.

5.5 Drainage Strategy Plans

5.5.1 Concept

Drainage strategy plans should incorporate a commitment to:

- Making use of natural materials and landscape features
- Minimising the carbon footprint of drainage infrastructure
- Minimising maintenance and operating costs
- Using water efficiently
- Using materials from sustainable sources (with due recognition given to factors such as transport distance).

Council submissions should set out how each of these objectives has been addressed in the relevant development. The plans should reflect an integrated approach to water management, with resources being conserved and the environment protected in the most sustainable way that can reasonably be achieved while allowing the development to proceed.

5.5.2 Natural conditions

Drainage design should consider the natural state of the catchment, wetlands and watercourses prior to settlement as well as their pre-development state. Where the existing conditions can reasonably be modified to simulate more closely those existing prior to settlement, consideration should be given to incorporating such provisions in the drainage strategy.

Water quality targets for contaminant removal should be exceeded where the incremental cost is relatively small.

Where drainage corridors need enhancement with vegetation, endemic species and/or species well-adapted to predicted climate conditions should be planted to match natural conditions and offer a maximum chance of survival.

5.5.3 Carbon footprint

The drainage strategy should include an assessment of the carbon footprint of the relevant infrastructure and establish principles for reducing that footprint. Achieving the desired outcome may involve selecting pipeline materials with lower carbon emission rating, minimising tree removal, using low-maintenance systems, and/or providing riparian water supply to ensure the survival of vegetation along watercourses. Off-setting tree planting may be necessary where significant clearing has to be undertaken.

5.5.4 Integrated water management

The drainage strategy plan should consider the potential for water reuse to reduce run-off and the demand for potable water.

5.5.5 Maintenance and operations

The drainage strategy should consider whole-of-life costs of the infrastructure to ensure that maintenance and operations costs have been included in design considerations. The final design should take account of all the resulting costs that will be incurred by the drainage authority, and provide the authority with appropriate calculations and cost estimates.

In particular, the efficiency and costs of periodically removing and replacing soil and vegetation in bio-retention systems and ponds, and removing litter from traps or watercourses, contribute significantly to on-going maintenance and operation costs.

5.5.6 Water efficiency

The drainage strategy should include provisions to maximise the use of on-site water resources to:

- Sustain endemic flora and fauna
- Reduce the need for irrigation water supply from off-site
- Replenish groundwater supplies
- Avoid increased run-off from the site

The plan should maximise the use of vegetation requiring minimal irrigation and specify mulching and/or other measures to improve water efficiency.

5.5.7 Materials

Selection of materials should address the sustainable use of resources as detailed in the Material Information Sheets (Appendix A) and associated guidelines in Clause 9.

5.5.8 Climate Change

The confidence levels from climate change modelling are not sufficiently high to quantify projected changes that would affect stormwater designs in any particular location, but the designs should consider the possible future trends and, so far as reasonably practicable, offer scope for cost-effective incremental improvements over time. Other strategies to combat the possible effects of increased rainfall intensity may include setting aside land for developing future detention basins or widening floodways.

Designs should take account of the possible effects of sea level rise on outfall capacity, and particular consideration should be given to the potential impact of coastal shoreline retreat on the structural integrity of the outfall.

5.6 Water Sensitive Urban Design

Water sensitive urban design (WSUD) aims to “bring stormwater management out of pipes in the ground” and to treat the entire stormwater network as part of the urban environment.

While the primary focus of WSUD has been to improve water quality by establishing passive treatment elements in the flow stream, it also seeks to restore ground water infiltration rates, increase wastewater reuse and reduce peak flows and total run-off volume.

Most of the water quality improvement measures listed in IDM Clause 20 *Treatment* will help to reduce both total and peak runoff of stormwater. The retardation basins and small detention systems described in Clauses 18 and 19 have the potential to greatly attenuate stormwater flows and thus reduce peak flow rates. However, care should be taken to ensure that the resultant increased duration of stream-forming flow rates does not increase erosion in waterways.

Ground water infiltration measures can help to reinstate some of the infiltration otherwise lost from the natural water cycle, but several possible adverse effects should also be considered:

- Foundations and road subgrades may be damaged by soil saturation and loss of bearing capacity.
- Special measures may be required when buildings or roads are founded on expansive clays.
- Saline or acid sulphate ground conditions can be aggravated by infiltration
- Increased subsoil moisture may increase infiltration to sewers and sewer manholes
- Concentration of infiltration may result in surface seepage due to elevation of groundwater levels

Drainage strategies must acknowledge the type of impact predicted and include a strategy for future modifications or augmentation of the stormwater systems to compensate for the types of effects currently predicted. Such a strategy must take account of the design life of the system, the elements of the system that would be affected by the climate changes and the likely cost and technical difficulties of the later modifications compared to design allowances at system creation.

5.7 Urban Sustainability Design Elements

5.7.1 Integrated Design

For discharges to natural watercourses the objective should be to simulate the flows and water quality that existed prior to development. While this is very difficult to achieve where precincts have extensive areas of impervious surface, the integrated approach to open space design required by the Urban Landscape provisions of Victorian planning schemes and the variety of WSUD measures available provide the framework and tools to aim for such a sustainable result.

5.7.2 Retardation Basin and Small Detention Systems

These two types of detention storage are designed to reduce peak runoff flows by capturing stormwater and storing it temporarily before releasing it in a controlled way. The volume of the storage and the outlet design are critical to this.

For larger retardation basins multi-stage outlet structures have the advantage of reducing the peak flow for a range of storm sizes so that not just rare rainstorm events have their peak flows reduced. However, retardation basins do not reduce the total run-off since they are designed to empty before the next major flood event.

Retardation basins need to be carefully designed so that they do not cause an increase in stream bed erosion due to extended periods of stream forming flows.

Ideally retardation basins discharging to natural watercourses should be designed to simulate the full range of flows for an undeveloped catchment. In this way the geomorphology of watercourses is sustained.

Small detention systems are useful for reducing the size of connections to minor stormwater systems and for reducing the size of the smaller pipelines within that system in many cases.

5.7.3 Infiltration and Treatment

Wetlands, retention basins, swales and water gardens may be used to increase infiltration, for water treatment purposes or to provide water for reuse. The water treatment aspects are addressed in Clause 20 of the IDM. While stormwater infiltration is not addressed separately in Clause 16 of the IDM it is a vital aspect of sustainable stormwater management – a natural water table level is an important element of ecosystem support.

5.7.4 Reuse

Reuse is a “sustainable” measure but needs to be managed so that flows to the environment (such as riparian corridors and groundwater) are sufficient to sustain natural conditions. Environmental flows should be considered for any stormwater management system.

5.7.5 Minor Drainage System

Clause 16 of the IDM suggests that the minor drainage system should be an underground piped network to convey runoff from minor storms. WSUD principles encourage a moderation of this approach to improve stormwater quality, increase infiltration and sustain riparian corridors.

In appropriate circumstances consideration may be given to:

- Diverting water from road surfaces to verges, swales and rain-gardens
- Discharging stormwater from the minor system to watercourses and wetlands at sustainable rates
- Retaining run-off as sheet flow for as long as possible

5.7.6 Major Drainage System

So far as reasonably practicable, the major drainage system should use natural drainage pathways, but protect natural conditions by implementing retardation, infiltration, reuse and treatment systems that counteract the effects of development on runoff quality and quantity. Consideration should be given to using retardation basins reduce the size of infrastructure such as culverts, bridges, channels, and outfall structures required to convey the peak flow.

5.7.7 Wastewater Drainage and Disposal

So far as reasonably practicable, and subject to regulatory controls, the designer should ensure that the most sustainable solution for wastewater disposal is achieved, having regard to whole-of-life costs and benefits.

5.7.8 Decentralised Wastewater Treatment (and reuse) Systems

Decentralised wastewater treatment systems may already be installed in some urban fringe or semi-rural areas. These include traditional septic tanks as well as more sophisticated aerobic waste treatment systems (AWTS) and other less common variants. These are used to provide a standard of wastewater treatment that meets health and environmental guidelines.

On-site wastewater disposal presents a risk to the quality of surface waters in drainage systems. Areas where this may be a problem should be assessed in the design of any relevant stormwater drainage systems.

5.7.9 Road design features

The following design features would reduce stormwater run-off and thus the consumption of resources for the construction and maintenance of the stormwater system (Refer also Clause 4 of these Guidelines)

- Keep road pavements to the minimum width required for safety and access
- Use permeable pavement in parking bays beyond the road pavement
- Where safe and practicable, use permeable pavement in lightly-trafficked parking areas
- Where safe and practicable, exploit nature strips for swale drains or bio-retention systems
- Where safe and practicable, use shared pedestrian/traffic zones rather than dedicated footpaths

5.7.10 Carbon Footprint

The major impact of drainage systems in greenhouse terms (for rural and semi-rural areas) is usually not related to operational costs but rather to the costs incurred during construction. Application of the above principles results in a reduction in the construction effort and a corresponding reduction in the carbon footprint.

Note also that a reduction in irrigation requirements reduces the carbon footprint of irrigation works (and sometimes avoids the need for them) and thus reduces operational costs and greenhouse gas emissions.

5.8 Rural Sustainability Design Elements

5.8.1 Design Standards

Clause 17.3 of the IDM requires drainage design to reflect the hydrological methods and data contained within the latest issue of Austroads *Road Design Guidelines Part 5 Drainage – General and Hydrology Considerations* and any VicRoads Supplement to those guidelines, unless otherwise provided in the IDM. That document contains quite extensive provisions relating to flow attenuation and water quality improvement measures. However, it does not directly address other aspects of sustainability and, being targeted at road drainage, does not specifically address the issues of watercourse ecology and pollution from developments other than roads.

The Design Engineer should therefore have regard to relevant principles and elements of WSUD provisions as they apply to rural areas to ensure that the geomorphology and ecology of watercourses is not adversely impacted by developments.

5.8.2 Attenuating Run-off

Developments in rural areas should be provided with retardation, storage and infiltration measures that are designed to ensure that run-off from the development does not exceed pre-development levels in either peak flow or total volume. This will usually require on-site detention (or retardation measures) and/or infiltration measures.

Wetlands, ponds, water gardens or swales would enable water to infiltrate into the ground near to the areas where natural infiltration processes have been disturbed or eliminated by impervious areas in developments.

5.8.3 Stormwater Harvesting

Stormwater harvesting is a necessity for developments in most rural areas due to the absence of reticulated water supplies. A suitable harvesting system would harness the impermeable area of a development through use of roof tanks and dams. However, there will be times when these storage devices are full and rainstorms will cause overflows. Dams and tanks by their nature attenuate flows, but the overflows will in many cases need supplementary detention measures if developments are not to contribute to higher peak flow in extreme events.

5.8.4 Minor Drainage System

Minor drainage systems should be augmented with attenuation measures to ensure developments do not cause increased peak flows locally.

5.8.5 Major Drainage System

The major drainage system should make use of natural drainage paths, but protect natural conditions by implementing retardation, infiltration, reuse and treatment systems that seek to counteract any significant effects of development on runoff quality and quantity.

In most rural locations there will be no public sewerage collection system and treatment and disposal of wastewater will need to be undertaken on-site or on a precinct basis. Since wastewater needs to be treated to a standard that will not adversely affect its receiving environment, it will often be more cost effective to treat the water to a standard suitable for storage and reuse on site.

Depending on the standard of the treated effluent, the water may be suitable for process water, toilet flushing, sub-surface irrigation or surface irrigation.

This is a valuable part of a sustainable water cycle as it minimises disposal costs and reduces the need for harnessing off-site water resources. However, care needs to be taken to ensure that appropriate standards of treatment are maintained and surface waters are not adversely affected.

5.9 Pipe Materials

Sustainable material options including recycled plastics and concretes containing recycled aggregates or fibre reinforced concretes can be considered, provided that appropriate adjustments are made during manufacture and/or design to ensure that the products perform to the standards expected of their conventional counterparts. As in the case of recycled pavement materials, experience suggests that admixtures of up to 20% of the total material content of a product are unlikely to have serious adverse effects on its performance, while admixtures of up to 40% can often be accommodated with only relatively minor adjustments to established practices during design and installation.

In VicRoads Road Design Guidelines Part 7 Drainage, certain types of fibre-reinforced concrete pipes with diameters between 100mm and 750mm are permitted, and pipes over 750mm in diameter are permitted subject to special acceptance testing. Steel reinforced concrete pipes are permitted for diameters 225mm to 2100mm. The IDM also provides guidance for the design and installation of ribbed polyethylene and polypropylene pipes.

5.10 Stormwater Treatment

5.10.1 General

Treatment measures for stormwater are well documented in WSUD guides And IDM Clause 20 provides an overview of the design requirements applicable to the most commonly used WSUD devices.

5.10.2 Greener treatment

The passive forms of treatment outlined in IDM Clause 20 make use of natural processes to remove litter, sediment and nutrients from stormwater. Apart from the greener effects of the treatments, the use of such passive processes keeps energy and resource input to a minimum. While mechanical devices such as vortex gross pollutant traps, self-cleaning screens and rotary clarifiers may sometimes be necessary to achieve the desired water quality, these devices should be avoided where possible in order to keep treatment to the most sustainable level achievable.

In assessing the whole of life costs for available water treatment measures it is important to include the maintenance and renovation costs With particular attention being given to such aspects as mowing of grass and removal and disposal of contaminants and contaminated soil and filter materials.

5.10.3 Grass surfaces

While grass surfaces including swales can provide an effective treatment measure and reduce run-off, these areas require periodic maintenance. Some Councils may require particular grass types to be used to reduce the frequency of cleaning and mowing.

Grass surfaces are vulnerable to damage by wheel loads, especially where there is no barrier kerb to discourage vehicle access. Thus barrier kerbs with frequent openings and other forms of vehicle barrier should be considered in designs, especially where run-off is to be concentrated such as in swales.

Grass surfaces may be reinforced with mesh and grids of various types where a more durable permeable surface is required. (Refer Clause 4.7.1 of SIG).

5.10.4 Regenerative Stormwate Conveyance

Regenerative Stormwater Conveyance (RSC) is a series of step-pools atop a sand/woodchip media bed. RSCs convey, manage and treat stormwater runoff by reducing energy as flow moves from pool to pool, promoting infiltration into the media bed and native soils, and by removing pollutants through sedimentation and media filtration. RSC performs similarly to bioretention, but with the added benefit of conveyance, often eliminating the need for an outlet structure and reducing the use of pipe conveyance.

5.11 Recycled Water

In urban areas a supply of recycled water may be available to minimise consumption of potable water, and some urban developments may be large enough to incorporate an independent dual supply network.

Recycled water reduces the demand on potable water sources and conserves water resources. However, the construction and operation of a recycled system consumes additional materials and energy that may exceed the cost of supplying potable water. Where raw water is not in short supply it may be more sustainable to use the treated wastewater elsewhere.

Disposing of wastewater off-site requires separate internal and external drainage systems with adequate capacity.

Clause 6 Material Recycling and Reuse

6.1 Objectives

A sustainable approach offers benefits by reusing and recycling products or reducing the volume of material excavated in the first instance and can be applied to pavement materials, bedding and backfill materials; and trenchless technologies.

The design and installation of all related infrastructure should be in accordance with the requirements of the relevant Authority.

The objectives of this clause are to:

- promote the use of alternative materials and methods for installing associated infrastructure
- promote recycling and reuse of waste material
- ensure that issues such as minimising site disturbance and managing surplus material are addressed
- minimise removal of material from the site and its disposal to landfill

6.2 Earthworks and Lotfilling

Where possible a design that achieves a balance of cut and fill should be targeted. More importantly the designer should determine the most sustainable outcome considering options for a balanced cut and fill, retention of surplus materials on site, possible reuse of materials elsewhere, and as a last resort disposal of materials as waste. Where material has to be removed from site, the designer should consider all possible uses and destinations for the material.

When designing earthworks the Design Engineer should consider:

- minimising the amount of topsoil that is disturbed and removed
- identifying options for reuse of topsoil on the site
- incorporating surplus excavated material including topsoil into site features and landscaping
- configuring lot layouts so as to minimise the need for regrading and earthworks
- accounting fully for material to be removed from trench excavations, footings and swale drains

6.3 Pavement, Bedding and Backfill Materials

Using recycled materials as aggregates where they meet specification requirements is a sustainable alternative to natural gravels and sands or crushed rock.

Alternatives include manufactured sand, recycled crushed glass, recycled concrete, reclaimed asphalt pavement, and many industrial by-product materials. The Materials Section in Clause 9 can be used to determine the benefits of using a particular alternative by following the sustainability indicator methodology.

The specification for aggregates depends on the type of infrastructure. Council will expect the material being considered to meet grading, plasticity, durability and all other requirements outlined in the relevant specifications.

6.3.1 Manufactured Sand

Manufactured sand is a finely crushed aggregate and suitable for use in a variety of construction activities. Production includes crushing of the source material followed by screening and, in some cases, washing.

Manufactured sand is often utilised in concrete and asphalt mix design but can also be used as a proportion of the sand component in backfill and bedding material. Manufactured sand can be screened into discrete fractions and blended with natural materials to meet specification requirements.

The material is widely available in Australia.

6.3.2 Recycled Crushed Glass

Recycled crushed glass can be used as a complete substitute for, or supplement to, other backfill material. Glass crushed as an engineering material exhibits properties similar to those of coarse sand. Crushed glass, once reduced to the desired grading size, can be used as an alternative fine aggregate (i.e. the sand component).

The Department of Environment and Climate Change of New South Wales conducted trials using crushed glass as a pipe embedment material. It was found in the field trials that the material was easier to handle and spread than natural sand and exceeded the minimum compaction requirements of AS1289.5.6.1.

Studies of the use of crushed glass as an engineering material have been carried out in Australia and worldwide. The Packaging Stewardship Forum of the Australian Food and Grocery Council is sponsoring many of these studies and provide information on how existing specifications can be met using recycled crushed glass.

6.3.3 Recycled Concrete

Recycled concrete refers to all types of aggregates derived from the processing of concrete previously used in both precast concrete products and cast insitu concrete. Cement Concrete and Aggregates Australia list the types of recycled concrete products currently available which include Recycled Concrete Aggregate (RCA), Recycled Concrete and Masonry (RCM) and Reclaimed Aggregate (RA). These materials are often used in concrete mixes and pavement sub bases and can also be used as a component of bedding or backfill.

6.3.4 Trenchless Technology

Designers should consider the possibility of installing underground utilities by trenchless technology. This technology offers opportunities to minimise disturbance especially in busy streets and in sensitive areas where, for example, utilities cross a watercourse. Other benefits may include a substantial reduction in the volume of spoil from trench excavation (material that is generally sent to landfill) and in the requirement for backfill materials.

Trenchless technology has applications both for new installations and for rehabilitating or replacing existing assets.

Currently available rehabilitation technologies include localised repair techniques, installation of lining and replacement, allowing for on-line rehabilitation of pipelines without the need for trench excavations. Suitable techniques are applicable to existing utility lines including gas pipes, ducts, water pipes, sewers and potentially cables. Guidelines for using these techniques are available from the Australasian Society for Trenchless Technology website (http://www.astt.com.au).

6.3.5 In-situ reprocessing

The use of machinery to take excavated material and immediately separate, crush or grade that material to produce backfill on site has a high level of sustainability benefits.

6.4 Material Information Sheets

Conventional materials and their sustainable alternatives can be compared against one another by referring to the Material Information Sheets in Appendix A and associated guidelines in Clause 9.

Clause 7 Public Lighting

7.1 Objectives

The objective of sustainable lighting is to:

- Develop an efficient public lighting network that meets current requirements whilst minimising energy consumption and greenhouse gas emissions

7.2 Energy Efficient Luminaries

Street lights are typically the largest use of energy and hence a significant cost for Councils. This energy usage can be reduced significantly be replacing conventional mercury vapour luminaires with more energy-efficient devices.

Clause 26.2 of the IDM specifies that all public lighting should incorporate energy-efficient luminaires, with the replacement of older devices with high energy efficiency fluorescent tubes having been the most common response to that requirement. In recent years, rapid developments in smart lighting, alternative power sources and LED-based luminaires having led many Council to embark on extensive upgrade programmes in the interests of creating more sustainable infrastructure.

Comparative data on the reliability of T5 (the most commonly deployed energy-efficient fluorescent-tube) luminaires and LED luminaires suggests that, LED units, at 0.75%, suffer less early-service failure than T5 units, at 1.86%. Comparable data on 20-year failure rates have yet to be established for the LED units. The operating assumption at present is that a 10% failure rate will be experienced, similar to the 11.4% rate for T5 units, but this estimate may include an appropriate measure of conservatism.

The following paragraphs from the *Local Government Policy Framework 2014* published by the Victorian Greenhouse Alliances provide a useful overview of what is becoming an increasingly complex area of activity. National policy directions favour free negotiation between Councils and Distribution Network Service Providers (DNSP), and removal of the existing energy regulation system, but early experience in South Australia suggests that this process may discourage rather than promote innovation, with the parties becoming locked in a dispute without effective recourse to independent arbitration.

Purpose and Background

The purpose of this policy is to assist Local Governments and the DNSP to work collaboratively to fast track the roll out of sustainable public lighting across the State.

Objectives

The objectives of the public lighting policy are to:

- Establish ongoing replacement programs to more sustainable and lower cost technologies
- Increase knowledge of the performance of the lighting system
- Ensure costs are based on transparent information and opportunities to reduce cost and/or improve quality are central to decision making
- Improve the accuracy and transparency of street lighting asset data and OMR pricing
- Improve relationships between all players in the sector

Outcomes

Within the period 2014-2019, councils will seek to facilitate the following outcomes under this program:

- Complete the majority of the residential lighting bulk replacement program to energy efficient types
- Establish bulk replacement programs for major road lighting (in conjunction with VicRoads) in all DNSP areas
- Increase the availability of lighting technology options including:
  - standard and non-standard lighting options for major and minor roads
  - lighting controls and data monitoring systems
- Develop a position paper to clarify ownership, access and maintenance options available to Councils

- Collectively pursue activities that balance the need to lower cost and the requirement to improve the quality of the public lighting system through:
    - increasing transparency of public lighting tariffs (including build up costs)
    - sharing data on streetlight asset type, condition and maintenance history
    - improving data quality/accuracy
    - collectively tendering for public lighting services and materials (where relevant)
    - ongoing engagement and negotiations on pricing and service levels
    - the development of a sector-wide formal response to the 2016-20 EDPR

Energy-efficient street lighting is only one of several areas in which local government has engaged with DNSP over recent years in an effort to improve outcomes for all parties, the areas in question being:

- Demand Management
- Public Lighting
- New Technologies
- Data Exchange
- Climate Change Adaptation

This Clause of the SIG will be updated to provide further advice as consultation and policy formation proceeds.

Clause 8 Landscaping and Open Space

8.1 Objectives

This clause seeks to ensure that all landscaping is designed and implemented to deliver sustainable outcomes by, for example, including using recycled materials, using water efficiently and selecting materials from sustainable sources

8.2 General

All landscaping should be designed and constructed using best practice to ensure the landscape is environmentally sustainable.

8.3 Requirements

8.3.1 Environmentally Sustainable Landscape Design

The following sustainability issues are to be considered during design development and construction:

General

Sustainable landscapes are about positively responding to natural systems or a new ecology created when buildings and infrastructure are constructed to ensure that the landscape survives and thrives as part of an integrated living system. Sustainable landscape should be designed to minimise maintenance costs. No landscape is maintenance-free but, by using sustainable design and construction methods, ongoing maintenance costs, energy inputs, and the overall carbon footprint can be significantly reduced.

Water

Water usage is to be minimised by designing a landscape that does not require artificial irrigation where possible. Plants that can withstand extended dry periods and drought are preferred. Using mulch within planted beds conserves moisture within the soil and reduces weeds.

Water sensitive urban design (WSUD) principles should be applied to landscaping projects. Key strategies include:

- Minimizing water runoff
- Harvesting water runoff for reuse in the landscape
- Allowing water penetration into the ground so that groundwater systems are recharged by infiltration
- Constructing of water filtration systems such as rain gardens, sedimentation basins and wetlands planted with appropriate macrophytes to improve water quality, provide amenity, enhance natural habitat values and to protect waterways

Irrigation systems should be designed to utilise captured storm water runoff and/or recycled grey water.

Waterway restoration including erosion control and revegetation using indigenous riparian plant species will increase bio-diversity, enhance habitat values, improve amenity and recreation values, and protect water quality and overall waterway health.

Climate Change

Some preliminary information on the possible impacts of climate change for Victoria is available from sources such as the Department of Environment, Land, Water and Planning and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

The impacts of climate change will vary considerably between regions and current climate change modelling results have a wide confidence range. However, many climate scientists believe that extreme rainfall events will become more frequent, average annual rainfall will increase in some regions and decrease in others, and average temperatures and sea levels will increase significantly. There is some measure of consensus that landscape designs in Victoria, and particularly in inland Victoria, should reflect the possibility that dry spells will increase in length and frequency, further increasing the pressure on water resources, and the risks to life, property and landscapes associated with bushfires.

While some climate change impacts may be widespread, careful consideration will need to be given to those impacts with particular relevance for distinct environments such as coastal landscapes, inland agricultural lands, man-made and natural landscapes, highlands and lowlands.

Plant species selection for various landscape types including sports turf, lawns, and amenity plantings comprising trees, shrubs and groundcovers should take into account the potential impacts of climate change, with drought-tolerant species being favoured wherever possible.

Being relatively economical to establish and maintain, grass is a common landscape treatment... Warm season grasses are preferable, because they are green for most of the year, are more tolerant of hot periods and drought and generally demand less irrigation, fertilizer and other chemicals.

The turf industry is constantly developing new grass hybrids for use in sports turf and lawns. Advice on suitable species and hybrids should be sought from a suitably qualified turf consultant or horticulturalist. Grass species that can be invasive and have the potential to become a weed in the broader landscape should not be used.

Native grasses can be a suitable alternative to exotic grasses where informal grasslands requiring infrequent mowing are to be created. Many native grasses are drought-tolerant, do not require irrigation, fertilizing or pest control and are relatively inexpensive to maintain. However, effective weed control must be maintained.

When selecting trees, shrubs and groundcovers for amenity style planting within a new landscape, plants that can tolerate periods of hot temperatures, wind and periods of drought and do not rely on artificial irrigation should be preferred. Advice on suitable plant species can be sought from accredited nurseries, horticultural experts and institutions.

Traditional established gardens that are to be conserved due to their significance may require an increase in management resources to preserve their values. Management implications may include changes to irrigation and watering regimes and replacement planting due to potential increased plant losses.

When plant selection is largely driven by strict design requirements such as heritage conservation, plants that require more intensive maintenance will still be included within the landscape, and can be expected to require additional resources such as watering, pruning and fertilizing.

Existing landscapes that are likely to demand more intensive maintenance resources should be modified where possible to improve sustainability. Changes to the design or management might include:

- Replacing irrigation-intensive landscape treatments with non-irrigated solutions
- Replacing vulnerable plants with more robust, drought-tolerant species
- Improving soil health by composting and mulching to improve soil structure and conserve soil moisture

- Introducing water capture and other conservation measures for water reuse in the landscape
- Reviewing pedestrian and vehicle circulation to reduce soil compaction and root zone damage

Some climate change models predict that extreme rainfall and storm surges will increase in number and intensity. While the confidence limits on these predictions remain relatively low, planting design should be integrated with future civil and hydrological flood mitigation measures. Planting ephemeral and semi-aquatic plants within waterways, drains and constructed wetlands provides erosion protection, improves water quality, increases biodiversity and provides amenity.

Any increase in the number and frequency of storm surges will expose coastal environments and waterways to increased risk, with the nature and extent of the damage being further influenced by potential systemic increases in sea level. The protection of coastal landscapes, townships and waterways should include significant land rehabilitation and protection initiatives including revegetation in conjunction with any civil structural solutions.

Current climate change model projections suggest that average and peak wind speeds in Victoria will remain more or less similar to those experienced at present, although significant increases may be experienced elsewhere in Australia. Planting design including species selection and placement should consider local wind speed along with a range of other site-specific issues. Coastal landscapes, highlands and open plains are landscapes susceptible to high winds. In highly urbanized environments wind tunnel effects can be created between densely arranged buildings. Plants that naturally occur in exposed windy sites should be considered for use. Localised treatments such as screens and windbreaks can be employed to provide protection for planting. Young plants with undeveloped root systems are susceptible to damage from high wind speeds. Mature plants with poor form and structure are also susceptible to damage such as limb drop in high wind conditions. A suitably selected, healthy, well-formed plant is less likely to succumb to occasional high winds.

As previously noted, climate change projections suggest that bushfire risks will continue to increase. Careful plant selection will be required to ensure planting initiatives do not contribute to those risks. Information and guidelines are available for landscaping and plant selection in bushfire prone areas (refer CFA). Advice should be sought from local fire authorities when undertaking planting within such areas.

Plant selection should consider a range of factors, including:

- Fuel loading
- Litter creation
- Flammability of canopy
- Ember production
- Canopy connectivity to reduce fire spread via a continual fuel path

Well-placed vegetation with low flammability may actually help protect houses by:

- Reducing the amount of radiant heat received by a house
- Reducing the chance of direct flame contact on a house
- Reducing wind speed around a house
- Deflecting and filtering embers
- Reducing flammable landscaping materials within the defendable space (CFA 2011)

Renewable Resources and Energy Efficiency

Renewable energy such as solar is to be used to power landscape elements such as external lighting where possible.

To reduce the carbon footprint associated with landscape works energy efficiency should be uppermost when selecting and operating machinery and selecting materials during construction and ongoing maintenance.

Many materials used in landscape developments contain embodied energy from harvesting, mining or manufacturing processes. By reusing as many materials as possible embodied energy is saved and retained within the landscape as opposed to being wasted if disposed. Elements commonly used in the landscape can be sourced from reusable or recycled products including, pavers, rocks, concrete, gravel, mulch, timber for furniture, plastics for furnishings and fixtures, glass and rubber. Treated timber components should be reused or recycled so far as reasonably practicable to avoid high landfill disposal costs.

Renewable products are to be used wherever possible. E.g. Use timber sourced from renewable plantation timbers rather than old growth native forests or imported timbers particularly timbers harvested from threatened ecosystems.

Plant Selection and Use

Planting can be used to improve climate conditions around buildings, infrastructure and open spaces. When carefully designed the correctly selected, plants can be used to create wind breaks, provide shade in warmer periods, allow sunlight penetration during cooler months and filter dust. Planting should complement passive heating and cooling initiatives for energy efficient buildings.

Planting captures carbon dioxide and thereby contributes to carbon reduction in the atmosphere.

Planting native plants can create habitat for native fauna, improve native vegetation connectivity and provide vegetation corridors through which native fauna can move.

Preference should be given to plants that support native birds and insects to create a balanced micro-climate and reduce the need for intervention such as pest spraying Mulching should be used to improve water efficiency and reduce weed competition.

Landscaping solutions can incorporate food producing gardens irrigated by captured storm water or, where available, by treated grey water.

In highly developed urban areas where open green space is limited, gardens can be developed over hard surfacing such as roof tops, carparks and road pavements using specially designed materials and components to create an appropriate growing environment for plants. Irrigation for these gardens is to be sourced from captured runoff water or treated grey water.

Choosing plants that will suit the existing site conditions such as soil types, rainfall, slope and aspect enhances the long term viability of the landscape without the need for ongoing intervention such as watering, fertilizing and weed control which demands energy, chemical use and expense. Planting the right plant in the right place at a density that will achieve good ground cover reduces the need for maintenance once the planting is established. Plants that suit the existing site conditions will avoid the need for artificial irrigation and the associated energy and costs.

Drought-tolerant species should be considered where sites may be dry for long periods. Good drainage will be required to avoid water-logging of these species during wetter periods.

Consider reducing high maintenance landscape treatments with less maintenance intensive treatments e.g. substitute lawn with plants over organic mulch or permeable gravel or use drought tolerant grass species (such as native grasses) in place of traditional water dependent species.

Plant selection should consider numerous issues including the desired aesthetic outcome. In highly modified landscapes, plant selection may include indigenous, native and exotic species.

In an urbanized environment, the landscape has been heavily modified, with distinctive micro-climates, soils and hydrology and does not reflect natural conditions. The optimum plant choice will depend on a range of factors including the design intent, desired aesthetic result, site conditions, climate and implementation and maintenance resources. Urban plants need to tolerate radiant head from hard pavements and buildings, air pollution, high winds (particularly where wind tunnelling occurs), compacted soils and disturbance or damage from foot, cycle and vehicle traffic and from construction and maintenance works.

When diversity and contrast is desirable a range of indigenous, native and exotic plants may be used within a landscape. The key plant selection principles discussed above apply no matter what the origin of the plant is. However, no plant will withstand stressful conditions if it is not matched to the site conditions. When used or allowed to remain in certain environments, both exotic and native plants can become invasive pests.

Pest Control

Integrated pest management techniques should be adopted, and should seek to minimise or remove the need to apply chemicals. Plant species that are less vulnerable to insect attack and other pest and diseases should be used. Reducing the need for chemical sprays and applications protects waterways from potential chemical runoff, minimises impacts on non-target species, reduces OH&S issues and saves money. Pest management should include controlling grazing vermin such as rabbits and protecting planting with appropriate guards and barriers.

Soil Management

Soil management is to include the use of existing site soils where possible to avoid the need for importing soil. Strict environmental controls are required when importing soils to minimise the risk of spreading weeds and/or soil borne pathogens. Importing soil is costly and requires significant energy to mine and transport.

Site soil health is to be maintained by ensuring site soils are not contaminated by debris and chemicals and are not compacted by construction machinery. Soil health can be improved by introducing compost, retaining moisture levels and aerating by cultivation to support a healthy diversity of soil flora.

In areas where vegetation clearing has led to erosion of soil by water and wind, land rehabilitation including revegetation is to be employed to stop and reverse the loss of soils. Stabilising land through physical erosion control measures in conjunction with revegetation initiatives will over time rebuild soil profiles via the natural cycling of vegetation.

8.3.2 Protection of Existing Vegetation

Tree protection is to be undertaken in accordance with AS4970-2009.

Clause 9 Materials

9.1 Objectives

This Clause provides key sustainability information on alternative construction materials. Indicators have been developed that enable comparisons to be made between commonly-used construction materials and more sustainable options

9.2 General

This Clause provides key sustainability information on alternative construction materials. Indicators have been developed that enable comparisons to be made between commonly-used construction materials and more sustainable options

9.3 Methodology

9.3.1 Sustainability Indicators

Sustainability Indicators were developed in order to rate the environmental and sustainability performance of material types designed to serve similar purposes. The indicators cover:

- Using recycled materials
- Reducing the carbon footprint of infrastructure projects
- Reducing maintenance and operation costs
- Using water in more efficient ways
- Using materials from sustainable sources”

Two levels of indicators were developed; a common level of Core Indicators against which a variety of construction materials within each of the categories in Clause 9.2 were rated; and a second level of Supplementary Indicators, against which materials were rated where possible and relevant (for example. water performance of pavers).

9.3.2 Material Information Sheets

Material Information Sheets for a range of materials in each category appear at Appendix A.

Table 1 Sustainability indicators

Core Indicators
Carbon
Recycled content
Cost
Geographic/regional/market availability
Supplementary Indicators
Water usage performance

Pollutants (other than greenhouse gas)
Reusability/Adaptability/Recyclability
Practical applicability

Each material has been given a score out of five against each indicator. The table below provides the rating rationale. This rating was based on quantitative data where possible (e.g. a comparison of embodied carbon, or recycled content). Where this was not possible, the rating was based on qualitative data (for example a description of the impact of the material on water flows, or the potential for pollutants to be emitted during the manufacturing process).

Table 2 Core Indicators rating

Core Indicators	
Embodied Carbon	**Rating**
very little embodied carbon	5/5
some embodied carbon/major improvement	4/5
some embodied carbon/slight improvement	3/5
moderate embodied carbon	2/5
high embodied carbon - manufacturing process	1/5
very high embodied carbon- extraction and manufacturing process	0/5
Geographic Availability	**Rating**
regional - local suppliers	5/5
regional - large company	4/5
available within the state - manufactured in state	3/5
available within state - imported product	2/5
interstate product	1/5
international product	0/5
Cost	**Rating**
low whole-of-life cost, low initial investment	5/5
low whole-of-life cost, high initial investment	4/5
moderate cost	3/5

Core Indicators	
high whole-of-life cost, low initial investment	2/5
high whole-of-life cost, high initial investment	1/5
most expensive	0/5
Recycled Content	**Rating**
100% recycled content - always	5/5
potential for 100% recycled content	4/5
30-80% recycled content - always	3/5
30-80% recycled content - potential	2/5
less than 30% recycled content	1/5
none	0/5

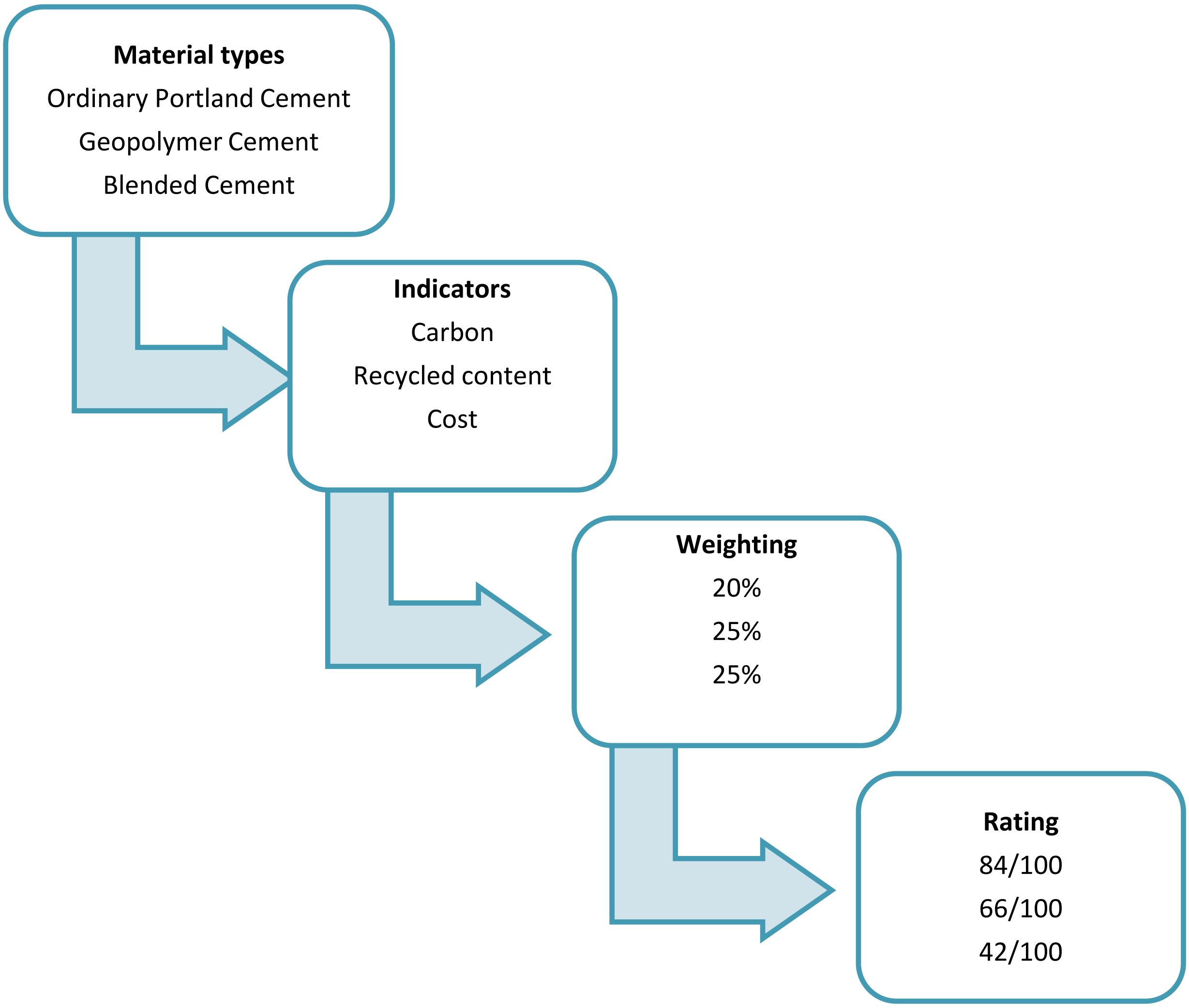
Table 3 Supplementary Indicators rating

Supplementary Indicators	
Water Usage	**Rating**
no water usage	5/5
some water usage/major improvement	4/5
some water usage/slight improvement	3/5
moderate water usage	2/5
high water usage - manufacturing process	1/5
very high water usage - extraction and manufacturing process	0/5
Pollutants	**Rating**
no pollutants	5/5
some pollutants/ - major improvement	4/5
some pollutants/ - slight improvement	3/5
moderate pollution	2/5
high pollution - manufacturing process	1/5
very high pollution - extraction and manufacturing process	0/5

Supplementary Indicators	
Reusability	**Rating**
100% recyclable - always	5/5
100% recyclable - potentially	4/5
partially recyclable - always	3/5
partially recyclable - potentially	2/5
sometimes recyclable	1/5
not recyclable	0/5
Applicability	**Rating**
improved performance	5/5
applicable to all baseline applications	4/5
applicable to most baseline applications	3/5
applicable to some baseline applications	2/5
mostly not applicable	1/5
not applicable to any baseline applications	0/5

Figure 1 below illustrates the process undertaken from selection of the material and alternatives to developing a final weighted score.

Figure 1 Example materials rating process



9.3.3 Weightings

The weighting system applied to the indicators reflects the consensus view of members of the Technical Committee of the Local Government Infrastructure Design Association and allows the aggregated ratings to be presented as a final score out of 100.

The weighting system has been designed so that the four core indicators generally account for between 75% and 85% of the final score with the remaining 15% to 25% being assigned to the supplementary indicators.

While subjective in character, the weightings reflect the best information available at the time when they were developed.

The weightings used are shown in the following tables

Table 4 – Core Indicator Weightings (totalling 80% of score)

Material	Embodied Carbon	Recycled content	Cost	Geographic / regional / market availability
Cement (fully worked)	20%	20%	20%	20%
Cement	20%	20%	20%	20%
Concrete reinforcement (rebar)	10%	25%	20%	20%
Concrete reinforcement (pipes)	10%	25%	20%	20%
Asphalt	20%	20%	20%	20%
Spray Seals	15%	20%	20%	20%
Plastic (piping)	20%	20%	20%	20%
Solar powered street lighting	20%	20%	20%	20%
Aggregate (bedding and backfill)	15%	25%	25%	20%
Aggregate (pavements)	15%	25%	25%	20%
Concrete pavement rehabilitation	15%	25%	25%	20%
Timber	20%	20%	20%	25%
Steel	10%	25%	20%	20%
Steel galvaniser	25%	0%	25%	25%
Pavers (clay)	25%	25%	25%	15%
Pavers (stone)	20%	20%	20%	15%
Pavers (concrete)	20%	20%	20%	15%

Table 5 – Supplementary Indicators Weightings (totalling 20% of score)

Material	Water usage performance	Pollutants (other than greenhouse gas)	Reusability / Adaptability / Recyclability	Practical applicability
Cement (fully worked)	7.5%	2.5%	0.0%	10.0%
Cement	7.5%	2.5%	0.0%	10.0%
Concrete reinforcement (rebar)	5.00%	7.50%	2.50%	10%
Concrete reinforcement (pipes)	5.00%	7.50%	2.50%	10%
Asphalt	5.00%	2.50%	0.00%	13%
Spray Seals	15%	20%	20%	20%
Plastic (piping)	10.00%	10.00%	0.00%	0.0%
Solar powered street lighting	5.00%	5.00%	5.00%	5.00%
Aggregate (bedding and backfill)	2.50%	2.50%	5.00%	5%
Aggregate (pavements)	2.50%	2.50%	5.00%	5%
Concrete pavement rehabilitation	2.50%	2.50%	5.00%	5%
Timber	7.50%	2.50%	0.00%	5%
Steel	5.00%	7.50%	2.50%	10%
Steel galvaniser	7.50%	7.50%	0.00%	10%
Pavers (clay)	2.50%	2.50%	0.00%	5%
Pavers (stone)	10.00%	5.00%	0.00%	10%
Pavers (concrete)	10.00%	5.00%	0.00%	10%

9.3.4 Core Indicator weightings rationale

Carbon

This indicator rated the *life-cycle* or *embodied* carbon in each material type.

Embodied carbon includes the greenhouse gas emissions that have resulted from all stages of the product life-cycle including extraction, processing and transport. In recent years, methodologies for estimating the embodied carbon or embodied energy in a product have improved and studies utilising these methodologies have been carried out in numerous countries. While the bulk of studies have been carried out in Europe and North America, some information also exists for materials used in Australia.

Ambrose et al (2002) explain the process involved in undertaking an embodied energy (or carbon) analysis:

> *Embodied energy analysis involves identifying energy consuming processes and calculating their contribution within the total product creation process. This usually involves several individual actions.*
>
> *To be able to quantify the energy embodied in the construction of an asset, the quantities of materials must first be estimated through a process of disaggregation and decomposition to a level of detail which allows for the separation of components into their principal materials. Energy intensities of each material can then be multiplied by the quantities of individual materials and the products aggregated to obtain the total for each material, element or whole building. In addition to the embodied energy value, other environmental indicators can also be calculated, such as CO2 emissions. This is the basis of LCA work and although not considered in this report it is another important aspect to consider.*

The levels of embodied carbon in construction materials quoted in these guidelines were determined on the basis of careful review of the study results available at the time of publication, and will be reviewed as better data emerges...

When specific life-cycle analyses had been undertaken, the data from those reports was used with Australia data being selected where available. Where this was not possible, the most current European or North American data was used.

In some cases, where data was particularly scarce for a given material type, comparison between data sets was necessary, and in other cases assumptions were made about material densities, and other factors. Finally, where qualitative figures were not available, reported percentage reductions (e.g. "*a typical geopolymer blend will have 60% less embodied energy than OPC*") were used as the basis for developing figures.

Where multiple reports were found, data was compared to ensure that the figures chosen for this report were representative of the range of data presented in these reports. Results (even if local) that were significantly higher or lower than average would have been discarded when identified, but in general, taking geography into account, data proved to be consistent.

The ratings, presented as scores out of five, were developed by comparing the embodied carbon for the baseline material and the two sustainable alternatives. For example, the researched embodied carbon (kgCO_2/t) in the three cement alternatives are shown in **Figure 2** below with an explanation of how the ratings were assigned**.**

Figure 2 Worked example for Sustainability Indicator ratings

Table 4 Embodied carbon in cement alternatives

Material	$kgCO_2/t$	Rating
Ordinary Portland cement (OPC)	806	0/5
Geopolymer cement	452	4/5
Blended cement	573	3/5

Ordinary Portland cement has the highest embodied carbon of the three alternatives, is therefore the least sustainable option, and is rated zero (see also tab *'Cement (fully worked)'* in Appendix A). Blended cement has lower embodied carbon and is scored 3/5. Geopolymer cement, with the lowest embodied carbon of the three alternatives is scored 4/5. Given that there is still a significant amount of embodied carbon in the *sustainable* alternatives; neither was scored 5/5.

Available data on embodied carbon was selected that considered emissions associated with extraction, manufacture and transport of the materials.

The weighting for embodied carbon across material categories was generally set at 20%. Where embodied carbon was considered the most significant consideration (for example in cement production, where energy use is extremely high) the weighting was raised above 20%. Where embodied carbon was considered less significant (for example in the comparison between steel reinforced concrete and fibre reinforced concrete) the weighting was lowered below 20%.

Recycled content

This indicator reflects the post-consumer recycled content used in the production of each material. The ratings, presented as scores out of five, were developed by comparing the recycled content for the baseline material and two more sustainable options. Higher ratings were given to the options with the highest proportion of recycled material, and lower ratings to those with the lowest proportion of recycled material.

The weighting for recycled content across all material types was generally around 20%, recognising the importance of considering recycled content in sustainability decision making. Where recycled content was considered the most significant consideration (for example, in steel production where there are opportunities for using very high proportions of recycled material) the weighting was raised above 20%. Where recycled content was considered less significant (for example, in steel galvanising, where no options with recycled content are available) the weighting was lowered below 20%.

Cost

This indicator reflects the relative cost of each material including, where relevant, operational and maintenance costs. The ratings, presented as scores out of five, were developed by comparing the cost for the baseline material and the two more sustainable options. Higher ratings were given to the least expensive options, and lower ratings to the most expensive options.

The weighting for cost across all material categories was generally around 20%, recognising the importance of considering the financial viability and competitiveness of new, more sustainable, materials and products.

Geographic/regional/market availability

This indicator reflects whether the material is readily available from local suppliers to the Councils which are members of the Local Government Infrastructure Design Association. The ratings, presented as scores out of five, are developed by comparing the extent to which the options were locally available. Higher ratings were given to options with the widest local availability, and lower ratings to those with the most restricted local availability.

The weighting for availability across all material types was generally around 20%, recognising the importance of locally available products and encouraging the growth of local sustainable supply chains.

9.3.5 Supplementary Indicator weightings rationale

Water usage performance

This indicator reflects the water intensity associated with the life-cycle of the material, where this information was available. The ratings, presented as scores out of five, were developed by comparing the water usage performance for the baseline material and the two more sustainable options. Higher ratings were given to options that consumed least water, and lower ratings to those that consumed most water over their life-cycle.

The weighting for water usage performance varied according to the extent to which water use is significant in the production or use of the material. A higher weighting was chosen where the initial production of the material was water-intensive, or where some or all of the options could facilitate better water management over their life-cycle. Permeable pavers are one example of such an option.

Pollutants (other than greenhouse gas)

This indicator reflects the quantity and impact of non-greenhouse gas pollutants such as toxic substances and particulates produced over the life-cycle of the material, where this information was available. The ratings, presented as scores out of five, were developed by comparing the extent to which pollutants are emitted or discharged during the production of the baseline material and the two sustainable options. Higher ratings were given to the least damaging options, and lower ratings to most damaging options.

The weighting for pollutants varied according to the extent to which pollution emissions are significant in the production or use of the material. The weighting was higher where the production of the material was considered to be highly polluting or toxic. Galvanised steel is one example of such an option.

Reusability/Adaptability/Recyclability

This indicator reflects the extent to which the material can be reused or recycled at the end of its life-cycle, where this information was available. The ratings, presented as scores out of five, were developed by comparing the reusability of the baseline material and the two more sustainable options. Higher ratings were given to the most sustainable options, and lower ratings to the least sustainable options.

The weighting for reusability varied according to the extent to which reuse of the material at the end of its life-cycle is possible and economically viable The weighting was higher where an option enabled improved reuse opportunities for that material category, and lower where all the options compared were fully recyclable.

Practical applicability

This indicator reflects the structural or functional performance of the material, where this information was available. The ratings, presented as scores out of five, were developed by comparing the extent to which options are suitable for all practical applications for which the baseline materials are used. Higher ratings were given to options that were useable in more applications, and lower ratings to options useable in fewer applications.

The weighting for practical applicability varied according to the extent to which sustainable options were useable across the range of applications for which the *baseline* (or non-sustainable) material is used. The weighting was higher where optional materials were not able to be used as a replacement for all applications. For example porous pavement is presented as a replacement for asphalt, but cannot be used in high-density or medium-density traffic applications.

9.4 Summary of Sustainability Scores

Table 6 presents the summary of the rating of each product against the core indicators and relevant supplementary indicators. These have been grouped to enable designers to compare the sustainability of each product within the group. In each group the higher the weighted score the more sustainable that product is.

The detailed assessment of sustainability and market availability of each product listed in Table 6 can be viewed in Appendix D.

Table 6 Summary of Product Sustainability Ratings.

Group	Materials	Weighted Score (out of 100)
Cement	Blended Cement	84
	Geopolymer Cement	81.5
	Ordinary Portland Cement (OPC)	48
Concrete Reinforcement	Glass fibre reinforcement	74.5
	Steel reinforcement	57.5
	Twisted Steel Fibre	55
	Polymer injection	40.5
Reinforced Concrete Pipe	Cellulose fibre reinforcement	61
	Steel Reinforcement	57.5
Asphalt	Warm Mix Asphalt (WMA)	76
	Recycled Aggregate Asphalt (RAA)	74.5
	Resin Bound Porous Pavement (RBBP)	69.5
	Hot Mix Asphalt (HMA)	50
Aggregates (natural sands and gravel)	Crushed concrete sand	95
	Crushed glass cullet (sand)	80.5
	Manufactured Sand	79.5
	Natural gravel and sands	49
Aggregates (crushed rock)	Crushed concrete	95
	Recycled gravel/reclaimed aggregates	90.5
	Recycled glass	75.5
	Crushed rock, virgin	45
Spray seals	Bitumen emulsions	52
	Cutback bitumen	45
Timber	Recycled Timber	92

Group	Materials	Weighted Score (out of 100)
	Australian Forestry Standard plantation timber	63.5
	Virgin timber	38
Steel	Recycled steel	89
	Polymer Injection Technology	71
	Structural steel	61.5
Pavers (clay)	Recycled clay pavers	87.5
	Low carbon pavers	81.5
	Natural clay pavers	39
Pavers (stone)	Recycled stone	87
	Permeable pavers	74
	Stone pavers	43
Pavers (concrete)	Geopolymer paver	80
	Concrete interlocking pavers	75
	Ordinary Portland Cement (OPC) paver	43
Plastic	Recycled HDPE pipe	88
	PVC -O pipe	58
	PVC pipe	33

9.5 Best practice examples

9.5.1 Warm Mix Asphalt Validation Project (VicRoads and AAPA)

Project	The use of warm mix asphalt (WMA) on the Hume Highway in Melbourne (validation project)
The Drivers	WMA is more sustainable due to the lower temperature used for its preparation compared with hot mix asphalt (HMA)
Choice of materials/methods	The validation project consisted of several WMA and HMA types placed in a grid pattern on the Hume Highway in Melbourne. In addition, specific variations within WMA were tested with both new aggregates and variations from 10%-50% reclaimed asphalt pavement (RAP) being tested.
Problems and challenges	The validation project aimed at demonstrating the field performance of WMA in a difficult environment: wearing course asphalt on a multiple lane urban highway with heavy traffic.
Outcomes	The project has confirmed that WMA performs as well as HMA with the added advantages of: Being able to use more reclaimed asphalt pavement (RAP) Better compaction Being able to be transported over longer distances Providing greater comfort for workers Lower energy use and greenhouse gas emissions
Reference	www.aapa.asn.au

9.5.2 Permeable paving system (Brisbane City Botanic Gardens)

Project	The use of a permeable paving system in Brisbane City Botanic Gardens to avoid damage to pavements due to large tree roots pushing through the surface
The Drivers	Surface of pavement damage due to tree roots
Choice of materials/methods	The project consisted of over 250 m2 of permeable paving utilising free draining base and bedding layer, as well as a joining aggregate to secure the pavers. The system utilises the series of drainage holes which are formed on the surface. These holes are filled with a small aggregate to allow water to infiltrate, minimising stormwater runoff.
Problems and challenges	There were no particular issues with the installation and maintenance of the system.
Outcomes	The project has confirmed that permeable pavement can: Reduce damage of large roots of trees (such as Morton Bay Figs) to push through the surface in search of water Reduce stormwater runoff, reducing downstream flooding and potential pollution Enhance aesthetics of surfaces Reduce risk of pedestrians tripping over raised surfaces
References	www.australmasonry.com.au

9.5.3 Blended Concrete (Colorado Springs Airport – International)

Project	Concrete runway reconstruction at Colorado Springs Airport using fly ash in the concrete mix
The Drivers	The concrete pavement on the primary runway was showing signs of deterioration that appeared to be beyond what would normally be expected for a concrete pavement of its age, considering the aircraft loading and environmental conditions that the pavement had experienced.
Choice of materials/methods	Initial evaluation concluded that the primary cause of the runway's deterioration was alkali-silica reactivity (ASR), which is a chemical reaction between the alkali in the cement and silica in the aggregates. The research undertaken to identify solutions recommended changes to the previous specifications by the Federal Aviation Administration (FAA), such as more extensive testing of the aggregates; more restrictions and testing of the cement and fly ash; and limitations on the total alkalis allowed in the concrete mix. The concrete mix design for this project used 30% fly ash to mitigate the ASR potential in the aggregates that they selected to use. The mix design 28-day flexural strength averaged 5,275 kPa, with the lowest being 4,964 kPa. The average was 482 kPa (17%) over the required 4,482 kPa. The mix design showed that a minimum flexural strength of 4,482 kPa would not be a concern.
Problems and challenges	This project was not intended to be a research project. Construction needed to proceed to meet the project delivery schedule; therefore, more extensive testing was not required. As the additional research is completed for the effects of ASR on concrete pavement, those results should be incorporated into future paving projects
Outcomes	Ongoing research is showing that additional measures need to be taken to produce Portland cement concrete pavement that is less susceptible to the detrimental effects of ASR aggregates that are causing severe damage to the concrete pavements. This project added those additional measures and has shown that it is practical and cost-effective to include those additional requirements in a normal paving project. Fly ash used as a cementitious material can: Generally make concrete more workable and can improve finishing Reduce the heat of hydration and delay set times, reducing thermal stresses in early age concrete Increase the ultimate strength of concrete Make concrete more durable, particularly to mitigate ASR and sulphate attack Reduce the CO2 footprint of concrete and reduces the embodied energy Reduce disposal in landfills and also address the issue of high potential hazard to groundwater contamination Reduce the cost of concrete depending on the hauling distance from the source of production
Reference	http://www.iprf.org/products/IPRF_Research_Report_Final_apr2011.pdf

9.5.4 Glass fines/Cullet in Asphalt (International - Wisconsin)

Project	The use of post-consumer glass in road construction projects in the state of Wisconsin (USA).
The Drivers	Most of the post-consumer glass recovered in the USA is used by container manufacturers to make new glass products. However, in order for this post-consumer glass to be accepted, it is to be free of most colour contamination, thus limiting the amounts communities and private recyclers can sell to such plants. Communities are therefore left with the need to find a use for the crushed or mixed broken glass (MBG). Also, container manufacturers are often too distant, making transportation costs too high to be economically viable. Glass recycling programs typically need markets within 100 km in order to break even. In Wisconsin, some 34 counties fall beyond this boundary. Another reason is that some areas find a weak market for green glass because only seven U.S. manufacturers produce green glass. Finally, glass loads are sometimes rejected for not meeting cullet quality requirements because of contamination.
Choice of materials/methods	A survey was designed and distributed to Wisconsin towns, public and private recycling facilities, and potential users of post-consumer glass, including sand and gravel operations and road contractors. The goal of this research was to facilitate stronger markets for MBG glass throughout the state of Wisconsin by educating communities on alternative uses, such as road construction applications. As a result, numerous counties in Wisconsin have undertaken road construction projects which utilise post-consumer glass. For example, Oconto County started using post-consumer glass in 1994 for paving applications and road construction projects, and still does so today. Approximately 3 to 4 tons per month of green glass and 10 tons per month of clear glass are used during the road construction season. Black top and road base containing post-consumer glass is utilized all throughout Oconto County and has held up excellent according to County representatives. There are no additional costs for Oconto County to use glass, as the glass and rock are crushed together. For this reason, funding is part of the Highway Department budget. The Oconto County Highway Department and Oconto County Solid Waste plans to continue use of black top and road base containing post-consumer glass all throughout the County.
Problems and challenges	There was a lack of available equipment to process post-consumer glass for these projects. Those with the equipment were either unwilling to lease the equipment or were unable to do so due to the equipment being immobile. Another barrier to post-consumer glass projects was that initially, few potential users were interested. This was overcome as more users learned about the Department of Transportation's proposed glass use standards. A list of counties with access to equipment and counties without equipment who were willing to jointly purchase or lease equipment was made available.
Outcomes	Considerable amounts of difficult to recycle, post-consumer glass are used in road projects throughout the world with significant environmental and commercial benefits and no reduction in functionality of the road base.
Reference	http://www4.uwm.edu/cbu/Papers/2000%20CBU%20Reports/CBU%202000-17.PDF

9.6 Market development

9.6.1 Legal and regulatory context

Division 3 of Part 9 of the Local Government Act 1989 sets out Best Value Principles (BVPs) through which Councils or local government entities (LGEs) are required to determine the most effective means of providing a service to the community. The Act also sets out a number of factors which Councils may take into account when applying the BVPs:

- The need to review services against the best on offer in both the public and private sectors
- An assessment of value for money in service delivery
- Community expectations and values
- The balance of affordability and accessibility of services to the community
- Opportunities for local employment growth or retention
- The value of potential partnerships with other LGEs and State and the Commonwealth governments
- Potential environmental advantages for the LGEs municipal district

9.6.2 The role of Councils

In 2010-201178, total local government expenditure in Australia was over $37billion[1]. Due to the considerable purchasing power[2] of Councils, and in the context of the above regulatory framework and the IDM, Councils can be seen to have a responsibility to encourage and in some ways develop markets for sustainable materials and products. Additionally, the IDM Group's intent in developing this section of the IDM is to enable local suppliers and contractors to increase the availability of sustainable infrastructure materials in regional Victoria and contribute to the growth of sustainable local economies.

It is well known that market forces drive innovation, leading to new and more advanced materials and products and ultimately to lower costs of those new materials and products. Procurement policies and practices can therefore be a key to developing markets and a viable supply chain for sustainable materials and products in a region. The challenge is to develop procurement policies that encourage new developments and sustainable supply chains, while maintaining the BVPs and satisfying community expectations for economic, social and environmental sustainability.

The aims of sustainable procurement policies and practices are to:

- Provide markets for new environmentally preferable products
- "close the loop" on recycling, improving the viability of recycling
- Provide leadership to the community
- Encourage industry to adopt cleaner technologies and produce products with lower environmental impacts.

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[1] *5512.0 - Government Finance Statistics, Australia, 2017-18*, ABS

[2] In the December quarter of 2017/18 alone, government expenditure on construction represented over $8billion of which spending Councils control or are associated with a significant percentage – roads alone constitiute $4 billion per year for local government.(Ref: *8762.0 - Engineering Construction Activity, Australia, Dec 2018, ABS, and Australian Local Government Association Submission to the 2017-2018 Federal Budget*).

Underlying these aims are the imperatives of value for money, functionality and safety. However, the lowest price isn't necessarily an indicator of best value for money, particularly when whole of life and other criteria such as environmental factors, and social and economic development considerations are included in the decision.

While the development of a procurement policy is beyond the scope of this study (Manual), there are many ways by which Councils can encourage the development of markets (supply and demand) by:

- Including a clear statement in all relevant tenders that gives notice to potential suppliers of the intention to consider environmental issues in the purchasing decision
- Integrating environmental factors into purchasing decision making including for example:
  - specifying that a product or service is to meet specific environmental performance requirements
  - allocating a specified proportion of the selection criteria on environmental performance
  - specifying a requirement for the supplier to be accredited to international and national environmental management system (AS/NZS ISO 14001)
  - specifying the maximum embedded energy or carbon of a material or product
  - specifying the water or energy consumption rating of the product

9.7 Carbon Footprint

This section is included to present the specific data collected during the researching of the embodied carbon information for the range of materials.

Where specific life-cycle analyses had been undertaken, the data from these reports was used; Australia data was selected where available. Where this was not possible, the most current European or North American data was used. In some cases, where data was particularly scarce for a given material type, comparison between data sets was necessary, and in other cases assumptions were made about material densities, for example. Finally, where qualitative figures were not available, reported percentage reductions (e.g. "*a typical geopolymer blend will have 60% less embodied energy than OPC*") were used as the basis for developing figures.

Where multiple reports were found, data was compared to ensure that the figures chosen for this report were representative of the range of data presented in these reports. It was intended to discard data (even if local) that was significantly higher or lower than comparable data, however this was not required, as in general (taking into account geography) data was consistent.

9.7.1 Cement

The data presented here shows the embodied carbon associated with the final concrete, taking into account the alternative cement mixes.

Embodied carbon in cement

Product	$kgCO_2/m^3$
OPC	336
Geopolymer cement	188
Blended cement	239

Information on embodied carbon was gathered from:

- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Costs and carbon emissions for geopolymer pastes in comparison to ordinary portland cement Benjamin C. McLellan, Ross P. Williams, Janine Lay, Arie van Riessen, Glen D. Corder
- EcoBlend, Independent Cement and Lime Pty Ltd, Victoria

9.7.2 Concrete reinforcement

The data presented here shows the embodied carbon associated with the final concrete, taking into account the alternative reinforcements.

Embodied carbon in reinforced concrete

Product	$kgCO_2/m^3$
Steel reinforced concrete	336
Glass-fibre reinforced concrete (with geopolymer)	101
Polymer injection steel reinforced concrete	319
Twisted Steel Fibre Reinforcement	Not available

Information on embodied carbon was gathered from:

- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Don Wimpenny, Peter Duxson, Tony Cooper John Provis, Robert Zeuschner, 2011, Fibre reinforced geopolymer concrete products for underground infrastructure, Victorian Science Agenda Investment Fund (and consortia)
- Onesteel, 2010, Building a sustainable future sustainability REPORT 2010 (note: figure assumes 5% improvement based on averaged statistics provided on p19)

9.7.3 Reinforced concrete pipe

The data presented here shows the embodied carbon associated with the final concrete, taking into account the alternative reinforcements.

Embodied carbon in reinforced concrete pipe

Product	MJ/kg
Steel reinforced concrete pipe	2.12
Cellulose-reinforced concrete	2.08

*Note data for steel reinforcements was not found in CO2e, but MJ (mega Joules). This information is directly comparable, however without knowing the breakdown of where the energy is consumed (e.g. transport, electricity) it is not possible to accurately convert to CO2e

Information on embodied carbon was gathered from:

- Prof. Geoff Hammond & Craig Jones, 2011

9.7.4 Asphalt

The data presented here shows the embodied carbon associated with the final asphalt mix.

Embodied carbon in asphalt

Product	$kgCO_2/m^3$
Hot mix asphalt	1013
Warm mix asphalt	709
Resin-bound porous pavement	507
Recycled aggregate asphalt	648

Information on embodied carbon was gathered from:

- D. . Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Cook, I & Knapton, J, 2009 (note: figure for resin-bound porous pavement assumes embodied carbon less 50% of standard pavement based on information on p1.)
- ARRB Group January 2009

9.7.5 Aggregates (natural gravels and sands)

The data presented here shows the embodied carbon associated with ready-for-use gravels and sands.

Embodied carbon in aggregates (natural gravels and sands)

Product	**$kgCO_2/m^3$**
Aggregates (natural gravels and sands)	51
Manufactured sand	No data
Crushed glass cullet (sand)	38
Crushed concrete (sand)	38

Information on embodied carbon was gathered from:

- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Sustainable Aggregates South Australia, 2010 (note figure for crushed concrete assumes embodied carbon 30% less than virgin material based on information on p5)
- The Energy and Resources Institute, 2004 (note figure for crushed glass cullet assumes embodied carbon reduction of 26% when compared to virgin material based on information on p105)

9.7.6 Aggregates (crushed rock)

The data presented here shows the embodied carbon associated with ready-for-use crushed rock aggregates.

Embodied carbon in aggregates (crushed rock)

Product	**$kgCO_2/m^3$**
Aggregates (crushed rock)	51
Crushed concrete (rock)	25
Recycled/reclaimed aggregates	2.59

Information on embodied carbon was gathered from:

- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Ecoinvent Database v2.1

9.7.7 Spray seals

The data presented here shows the embodied carbon associated with the final bitumen mix, taking into account the alternative bitumen binders.

Embodied carbon in spray seals

Product	$kgCO_2/t$
Cutback bitumen	62
Crushed concrete	23

Information on embodied carbon was gathered from:

- AustRoads, 2008

9.7.8 Timber

The data presented here shows the embodied carbon associated with ready-for-use timber products.

Embodied carbon in timber*

Product	MJ/m^3
Timber (hardwood) sawn, planed, kiln dried	396 (-838)
timber (softwood), sawn planed, kiln dried	204 (-718)
Recycled timber	24

*Note: the figure outside the brackets is the added fossil fuel and other components for producing the finished product. It does not include carbon sequestration benefits. The figures inside the brackets are negative and include carbon sequestration benefits. Information on embodied carbon was gathered from:

- Australian national LCI DB (2008, Dried sawn wood product) via •D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Ecoinvent Database v2.1 (transport and recycling component only)

9.7.9 Steel

The data presented here shows the embodied carbon associated with ready-for-use steel.

Embodied carbon in steel

Product	$kgCO_2/m^3$
Virgin steel*	12,207
Recycled steel (reinforcing bar)**	7,295
Polymer injection technology steel	11,597

*Note: includes industry norm 20% recycled content

Information on embodied carbon was gathered from:

- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010

- **Onesteel 2008 Enironmental Product Declaration(s) for Reinforcing Rod, Bar and Wire compared with Hot Rolled Structural and Rail. Note that the result is identical to World Steel LCA outcomes ratio for rebar versus structural steel as expressed at
- https://www.steelconstruction.info/End_of_life_LCA_and_embodied_carbon_data_for_common_framing_materials#Construction_product_information
- Onesteel, 2010 (note: figure assumes 5% improvement based on averaged statistics provided on p19)

9.7.10 Pavers (clay)

The data presented here shows the embodied carbon associated with ready-for-use clay or clay-substitute pavers.

Embodied carbon in pavers (clay)

Product	**$kgCO_2/m^3$**
New clay pavers	1,920
Low carbon pavers	139
Recycled pavers	1,344

Information on embodied carbon was gathered from:

- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Sustainable Aggregates South Australia, 2010 (note figure for recycled pavers assumes embodied carbon 30% less than virgin material based on information on p5)

9.7.11 Pavers (stone)

The data presented here shows the embodied carbon associated with ready-for-use stone pavers or permeable pavers:

Embodied carbon in pavers (stone)

Product	**$kgCO_2/kg$**
Stone pavers	0.05
Recycled sandstone pavers	0.035
Permeable pavers	0.025

Information on embodied carbon was gathered from:

- Cook, I & Knapton, J, 2009
- SImaPro, 2012
- Sustainable Aggregates South Australia, 2010 (note figure for recycled sandstone assumes embodied carbon 30% less than virgin material based on information on p5)

9.7.12 Pavers (concrete)

The data presented here shows the embodied carbon associated with ready-for-use concrete pavers:

Embodied carbon in pavers (concrete)

Product	$kgCO_2/m^3$
Concrete pavers	336
Geopolymer pavers	134
Concrete interlocking pavers	No data

Information on embodied carbon was gathered from:

- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010
- Net Balance Foundation Ltd, 2007 (note: figure for geopolymer paver assumes embodied carbon less than 40% of standard paver based on information on p14.)

9.7.13 Plastic (piping)

The data presented here shows the embodied carbon associated with ready-for-use plastic pipes:

Embodied carbon in plastic (piping)

Product	$kgCO_2/m$
PVC	8.76
PVC-O	5.49
Recycled HDPE	0.82

Information on embodied carbon was gathered from:

- Prof. Geoff Hammond & Craig Jones, 2011
- Australian Greenhouse Office, 2004
- Recycled Plastic Technology Pty Ltd, 2012

Note: Aus Greenhouse Office (2004) estimates 80MJ/kg for PVC. Hammond et al (2011) estimate 77.2MJ/kg and 2.41CO2/kg. This equates to a conversion factor of 32.04MJ/kgCO2. This conversion factor was used for all three plastic alternatives in lieu of data being available on the conversion of MJ to CO_2 in Australia for pipe production. Data provided by Recycled Plastic Technology was based on 375mm pipe, whereas data provided by Hammond et al (2011) was based on 100mm pipe. Whilst the company was contacted to request relevant data, at the time of writing contact has not been made, and the figure for HDPE was divided by 3.75 to enable comparison.

APPENDIX A MATERIAL INFORMATION SHEETS

A1 Cellulose Fibre Reinforced Concrete Pipes

1. BACKGROUND

Cellulose reinforced concrete pipes (CRCP) can be used as an alternative to the traditional steel reinforced concrete pipe. CRCPs are made from Ordinary Portland Cement, silica (ground sand particles), and cellulose fibre.

The addition of the cellulose fibre to the concrete results in the following advantages:

Longer lengths which decrease the pipe laying time

Improved durability due to the absence of potentially corrosive steel products

Lightweight (approximately ½ the weight of steel reinforced pipe) composition means that transportation and installation is safer and more cost effective

Exceeds the AS/NZ53726:2007 strength requirements

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for CRCP.

Table A1.1: Core Indicators

Indicator	Information
Embodied Carbon	TBC
Recycled content	No recycled content
Cost	Whole of life costs are improved because of extended design life (no steel) and improved transportation and installation (30-40% faster installation) efficiencies
Geographic/regional/ market availability	Available in regional Victoria

Table A1.2: Supplementary Indicators

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Pollution reduction associated with steel extraction and processing
Reusability/Adaptability/ Recyclability:	100% recyclable for use as course aggregate
Practical applicability:	This product is suited to all applications that steel reinforced pipe is used. The lack of steel within the product means that it can be cut more easily and efficiently. The ability to reuse the off-cuts can also reduce overall waste.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use any waste products during concrete production, if not, is this an option?

b) Is this product compatible with alternative pipe embedment material?

c) Does this supplier have a distribution site close to the construction area?

d) Does the product manufacture process use recycled water or harvested rainwater?

e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A2 Inorganic Zinc Silicate

1. BACKGROUND

Inorganic zinc silicate (IOZ) coatings can be used as an alternative to the Hot-Dip process for steel corrosion protection.

IOZs are coatings made of metallic zinc secured in a glassy silicate matrix. The zinc provides corrosion protection through acting as a sacrificial anode to the steel. The zinc particles are in intimate contact with the steel and the porosity of the coating provides voids that contribute to ongoing protection of the steel. Over time the voids are filled by zinc corrosion products, which effectively control the zinc's depletion rate, and form a long-term barrier for the steel.

IOZ coatings are most suited to coastal areas, structures with long service lives and where long-term corrosion protection is required.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for inorganic zinc silicate.

Table A2.1: Core Indicators

Indicator	Information
Embodied Carbon	TBC
Recycled content	N/A
Cost	Reduced whole-of-life cost for long-term use and application in highly corrosive environments. The application cost will be higher due to the increased skill requirement for applicator and the process for applications is also longer and more time consuming.
Geographic/regional/ market availability	Regionally available

Table A2.2: Supplementary Indicators

Indicator	Information
Water usage performance	N/A
Pollutants (other than greenhouse gas):	VOC content is less than 10 grams per litre which makes it suitable for 'sustainable buildings' Hazardous waste from production process
Reusability/Adaptability/ Recyclability:	Non-recyclable
Practical applicability:	This product is not suitable on steel that cannot be abrasive blast cleaned such as thin-gauge steel or cannot be prepared and coated in shop under controlled conditions.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Are the applicators properly trained?

b) Does the preparation and application shop conform to emission requirements?

c) Does the manufacturer have a waste management plan and health and safety policy?

d) Does the product manufacture process use recycled water or harvested rainwater?

e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A3 Low Carbon Pavers

1. BACKGROUND

Low carbon pavers are pavers that use waste material and clay to create a functional 'clay' paver. There are a number of waste materials that could be used in this process, however the below listed are the current sources on the market:

Timber waste, discarded timber, sawdust etc.

Industrial waste, slag or fly-ash

Clay waste from manufacturing process

These pavers are fired and manufactured through the same processes as standard clay pavers; however, the blend is altered to include the waste material. The blend for this alternative is largely dependent on the supplier, as there is no standard or restrictions on performance that prescribe the composition of the paver.

Performance of these pavers has been shown to meet requirements for commercial use.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for low carbon pavers.

Given the composition variety in the available products, the below information provides an indication of the environmental benefits associated with a clay paver that uses 80% recycled material (fly ash and waste pavers), and sustainable energy and water measures during the manufacturing process.

Table A3.1: Core Indicators

Indicator	Information
Embodied Carbon	Low carbon pavers can have up to 90% less embodied carbon than clay pavers (supplier and mix dependent).
Recycled content	80% recycled content
Cost	25% reduction in manufacturing costs A local company in Australia stated that the pavers would be on parity with virgin clay pavers but the overall project cost is reduced as the paver is lighter and easier to install
Geographic/regional/ market availability	This product is relatively limited Small number of examples are located in Victoria

Table A3.2: Supplementary Indicators

Indicator	Information
Water usage performance	82% reduction in water usage, without extraction of virgin materials
Pollutants (other than greenhouse gas):	Information not available Expected that pollution would be reduced as extraction of virgin materials is reduced
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Performance of the alterative pavers has been comparable to clay pavers in commercial and residential scenarios.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use recycled waste materials?

b) Are the waste materials sourced locally? If not, what is the transport impact?

c) Does supplier employ waste reduction measures within their operations?

d) Does the product manufacture process use recycled water or harvested rainwater?

e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A4 Recycled Clay Pavers

1. BACKGROUND

Recycled clay pavers and bricks are widely available throughout Australia. The recycling process generally uses waste clay and brick from the manufacturing process and also commercial/residential wastes obtained through construction processes.

The recycling process for waste clay and bricks can involve crushing the waste material to a state suitable for use in the manufacture of new clay products. For this process to be effective the waste material needs to be clean and free of cement, paper, plastic, metal or timber.

Another option for recycling is to collect bricks and pavers in good conditions and after cleaning re-sell in their original form.

Not all recycled clay pavers will be made from 100% recycled material; this will be dependent on the supplier.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for recycled clay pavers

Table A4.1: Core Indicators

Indicator	Information
Embodied Carbon	At least a 43% reduction in embodied carbon (this would represent the worst case CO2 reduction, assuming a high level of reprocessing)
Recycled content	100% recycled
Cost	At least 20% reduction in cost
Geographic/regional/ market availability	Recycled bricks and pavers are widely available Installers are available in regional Victoria

Table A4.2: Supplementary Indicators

Indicator	Information
Water usage performance	Significant water savings by eliminating the extraction process for virgin materials
Pollutants (other than greenhouse gas):	99% less SOx, 98% less NOx
Reusability/Adaptability/ Recyclability:	100% recyclable (as rubble or clean brick)
Practical applicability:	The mechanical and functional performance of the recycled product is equivalent to virgin clay pavers

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product optimise the use of recycled waste materials?

b) Are the waste materials sourced locally? If not, what is the transport impact?

c) What is the level of post-treatment to prepare the product for re-sale?

d) Does supplier employ waste reduction measures within their operations?

e) Does the product manufacture process use recycled water or harvested rainwater?

f) Does the supplier have an environmental management system?

g) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A5 Recycled Stone Pavers

1. BACKGROUND

Recycled stone pavers are widely available throughout Australia (e.g. sandstone blocks, granite pavers etc). The recycling process generally uses waste pavers or blocks from the manufacturing process and also commercial/residential waste obtained through construction processes.

The reprocessing for these products is minimal and will generally consist of re-shaping or cutting the blocks or pavers into the desired shape and size. The amount of reprocessing will be largely dependent on the intended use of the product. For example, sandstone blocks intended for retaining walls or landscaping will most likely be left *rustic* and variable in size, however, pavers intended for walkways would most likely need to be uniform and 'sculpted'.

The use of recycled stone reduces the need to quarrying and extraction of virgin material. This has significant environmental benefits related to water use, water quality, ecosystem and species disturbance/displacement, land quality and resource management.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for recycled stone pavers.

Table A5.1: Core Indicators

Indicator	Information
Embodied Carbon	Whilst researched material reported "major savings" in embodied energy using recycled stone pavers, specific data quantifying the savings was not located.
Recycled content	100% recycled
Cost	Cost will most likely be reduced assuming that the transportation impact is minimal
Geographic/regional/ market availability	This is a widely available product

Table A5.2: Supplementary Indicators

Indicator	Information
Water usage performance	Savings of at least 27l/t of material
Pollutants (other than greenhouse gas):	Not applicable
Reusability/Adaptability/ Recyclability:	100% recyclable product End of life, the product can be crushed and used as aggregate
Practical applicability:	Assuming that the stone is in good condition and is not contaminated it can be used for the same applications as virgin stone blocks and pavers

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product optimist the use of recycled waste materials?

b) Are the waste materials sourced locally? If not, what is the transport impact?

c) Does supplier employ waste reduction measures within their operations?

d) Does the product manufacture process use recycled water or harvested rainwater?

e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A6 Australian Forestry Standard Timber

1. BACKGROUND

There are currently two major plantation types across Victoria – Pine and Eucalypt plantations. The pine plantations (an exotic species) are grown for softwoods and the eucalypts (native) are grown for hardwoods.

AFS Timber is plantation timber that is certified by an independent body as being managed in accordance with the Australian Forestry Standard. Compliance with the standard is designed to improve the overall sustainability of the plantation management.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for AFS timber.

Table A6.1: Core Indicators

Indicator	Information
Embodied Carbon	In the case of plantation timber where forests are harvested and then replanted, the timber becomes carbon neutral. The growing tree will take up as much CO2 as the harvested one will eventually release
Recycled content	There is no recycled content in timber.
Cost	AFS timber will generally cost slightly more than non-certified timber.
Geographic/regional/ market availability	AFS timber is available locally in Victoria; however there is not currently sufficient plantation timber in Victoria to meet demand. As a result, Victoria currently imports a significant number of timber products from native forest and plantation harvesting overseas

Table A6.2: Supplementary Indicators

Indicator	Information
Water usage performance	AFS Certification includes requirements for the plantation manager to effectively manage water (e.g. minimise pollution)
Pollutants (other than greenhouse gas):	AFS Certification includes requirements designed to minimise any pollutants
Reusability/Adaptability/ Recyclability:	All timber products are 100% recyclable
Practical applicability:	AFS timber products are useable in all applications virgin timber is used

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Is the plantation third-party certified?

b) How long has the plantation maintained its certification for (uninterrupted)?

c) Is the timber locally harvested?

d) What is the transport impact of the timber

e) Can chain of custodies be produced?

f) For long-term contracts can an on-site inspection of the plantation be organised (environmental review)?

A7 Bitumen Emulsion

1. BACKGROUND

The predominant use of bitumen emulsions in Australia is for sealing works. They can be used as an alternative treatment to hot cutback bitumen on low-to-medium trafficked roads. Traditionally, bitumen is mixed with (0-8%) petroleum solvents (e.g. kerosene) to produce cutback bitumen that is the correct viscosity to make it workable. Bitumen emulsions can be applied to the road surface without the use of solvent.

According to the Asphalt Institute, almost 40,000 kJ of energy is required to process one litre of cutter. In comparison only 1151 kJ of energy is required to process one litre of bitumen emulsion.

Bitumen emulsions will however generally be less cost-effective due to the additional manufacturing process required between the refinery and road application.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for bitumen emulsion.

Table A7.1: Core Indicators

Indicator	Information
Embodied Carbon	Less embodied carbon (approximately 60% less) due to the heating required for hot cutback bitumen.
Recycled content	There is potential for the use of recycled tyres and rubber materials in the manufacturing process of Poly Modified Binders (PMB)
Cost	Generally cost more, however use of recycled material can reduce the cost
Geographic/regional/ market availability	Available in regional Victoria

Table A7.2: Supplementary Indicators

Indicator	Information
Water usage performance	30% reduction in water usage in production
Pollutants (other than greenhouse gas):	Reduced use of solvents
Reusability/Adaptability/ Recyclability:	Not reusable, but does not impact the reusability of asphalt
Practical applicability:	Road tests carried out in Australia and New Zealand between 1993 and 1997 revealed good performance of the material and no visual differences with seals constructed with standard distillate precoated aggregates. Whilst there is a need to tightly control traffic during the initial stages to minimise the early loss of aggregate, emulsion sprayed seals generally have equivalent performance to cutback bitumen and when applied under cooler and wetter conditions generally perform better than cutback bitumen applied under the same conditions.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use any cutter?

b) Does the product include any recycled tyres or other recycled rubber material?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

f) Is this a local supplier and manufacturer?

A8 Blended Cement (Supplementary Cementitious Materials - Scms)

1. BACKGROUND

Blended cement is manufactured for use in general purpose concrete applications including cement-based products, mortars and grouts. Blended cements contain Supplementary Cementitious Materials (SCMs), such as fly-ash from power generation and slag waste materials from iron and metal production, as a replacement for a proportion of the OPC.

This product is comparable to OPC cement for its performance, and is now used commonly in many infrastructure and construction applications.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for Blended Cement.

Table A8.1: Core Indicators

Indicator	Information
Embodied Carbon	SCMs have approximately 40% less embodied energy than OPC
Recycled content	Uses industrial waste (slag/fly ash) General composition is up to 30% SCM with remaining OPC
Cost	Cost is the same as OPC, with some suppliers offering discounts compared with OPC
Geographic/regional/ market availability	The cement mix is available from Port Melbourne and, can be supplied and mixed by any plant. Currently supply to regional Victoria

Table A8.2: Supplementary Indicators

Indicator	Information
Water usage performance	There is a water-use benefit associated with blended cements. This benefit is dependent on the amount of blended cement used in the mix, and also the type of SCM used Assume up to 15% reduction (best case, using approximately 30% SCM within cement mix)
Pollutants (other than greenhouse gas):	30% reduction in carcinogens and heavy metals
Reusability/Adaptability/ Recyclability:	100% recyclable product as crushed concrete aggregate
Practical applicability:	Extended structural life Reduced maintenance costs Can reduce heat island effects through lighter colour

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product optimise the use of industrial waste?

b) Does the product use industrial waste sourced close to the site

c) Does the product conform with AS3972 for General Purpose Cement

d) Is the plant energy efficient and/or does it have an Environmental Management System

e) Can the product use alternative sustainable aggregates?

A9 Crushed Concrete

1. BACKGROUND

Coarse recycled concrete aggregate (RCA) is composed of rock fragments coated with cement, with or without brick, sands and/or filler, produced to comply with tolerances for grading and minimum foreign material content, and supplied at a lower density than that for crushed igneous rock.

Waste material like steel and other contaminants are removed during reprocessing. Other materials that may be present in RCA are gravel, crushed stone, hydraulic-cement concrete or a combination thereof deemed suitable for premix concrete production. In Australia, RCA is one of the most common construction and demolition wastes used in concrete production both as coarse and fine aggregate.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for RCA

Table A9.1: Core Indicators

Indicator	Information
Embodied Carbon	30% reduction in processing compared with virgin material (based on assumption that transport would be no more than 5km more than the virgin material)
Recycled content	100% recycled content
Cost	On-site waste can be used Can purchase from supplier but the transportation distances should be kept low to maintain profitability
Geographic/regional/ market availability	Available in regional Victoria Very common product

Table A9.2: Supplementary Indicators

Indicator	Information
Water usage performance	The water performance during mixing is lower as the absorption rate is higher than with virgin aggregates
Pollutants (other than greenhouse gas):	Generally, similar to virgin material, no additional chemicals are required to process
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	RCA is applicable for most aggregate application Not more than 30-40% inclusion of this aggregate substitute product is recommended in a concrete mix If the crushed concrete is highly contaminated with brick (etc.) it should be used for backfill, cleaner products can be used for pavement and concrete mixes

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Is the supplier a local recycler?

b) Do the landfill levies paid by Council regarding their waste compensate for any additional cost?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

f) Is the material tried and tested?

g) Are the contaminant levels suitable?

A10 Crushed Glass Cullet (Glass Sand)

1. BACKGROUND

Crushed glass cullet (glass sand) is the waste material or *glass fines* that are produced during the glass recycling process. These fines are not suitable for reuse in recycled glass containers or bottles but can be used as a sand replacement within the construction industry. To prepare the fines for use they are screened, vacuumed, crushed and graded to produce unwashed glass sand. The glass sand is generally mixed with natural sand in varying proportions.

Whilst there has been some controversy surrounding glass cullet reuse due to concerns over it potentially containing crystalline silica, (a cause of silicosis and a known carcinogen), it is worth noting that tests completed by Sydney Water show that the dust generated by glass cullet is not considered hazardous and does not contribute to silicosis or cancer.

Crushed glass cullet can be used (as a proportion of natural sand mix) in any application where natural sand is used, for example, concrete aggregate, pavement sub base and base, asphalt, backfill and bedding, and paving applications. There have been limited case studies and trials to date in Australia using this product across all applications. (Not sure if this is accurate. There have been studies done for The Packaging Stewardship Forum of The Australian Food and Grocery Council for most of the applications listed)

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for crushed glass cullet (glass sand).

Table A10.1: Core Indicators

Indicator	Information
Embodied Carbon	Reduced embodied energy as the cullet is a 'waste' product from glass recycling processes
Recycled content	100% recycled content This produce is a waste material that would otherwise be sent to landfill
Cost	The cost for the recycled product (from recyclers) is cheaper than for natural sand assuming that the transportation distance is not significant
Geographic/regional/ market availability	Glass cullet is a widely available product, it is sold through recycling facilities, concrete manufacturers and some specialist providers

Table A10.2: Supplementary Indicators

Indicator	Information
Water usage performance	N/A (supplier dependent)
Pollutants (other than greenhouse gas):	No difference with natural sand, the risk of pollution could potentially be higher due to residual contaminants
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Crushed Glass Cullet can be used within most applications, as shown in the table below.

Indicator	Information
	As natural sands become more scarce and the transport distances to certain parts of the country increase, the cost efficiency of recycled glass cullet will be significantly improved

Common use for Natural sands	Glass Cullet suitable	Examples
Concrete aggregate	Yes	Local example could not be identified
Cement mix	Yes	Trials completed in NSW by DECC which shows partial replacement is suitable
Pavement Sub-base/Base	Yes	
Asphalt	Yes	
Backfill and bedding	Yes	VicRoads approved, DECC NSW approved
Paving applications	Yes	Successful trials completed in Waverly by Waverly Council, NSW

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Is the supplier of glass cullet a local recycler?

b) Do the landfill levies paid by Council regarding their waste compensate for any additional cost of the glass cullet?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

f) Is the material tried and tested?

g) Are the contaminant levels suitable?

A11 Geopolymer Paver

1. BACKGROUND

Geopolymer cement does not contain any Ordinary Portland Cement. Geopolymers are a type of inorganic polymer that can be formed at room temperature using industrial waste or by-products (fly-ash from power generation and slag waste materials from iron and metal production) as source materials to form a solid binder that looks like and performs a similar function to OPC.

Natural materials like kaolinite and clays could be used as an alternative to the industrial waste; however this would increase the use of the sodium silicate which is toxic and environmentally damaging.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for Geopolymer pavers.

Table A11.1: Core Indicators

Indicator	Information
Embodied Carbon	The embodied carbon in geopolymer cement is approximately 60% lower than OPC
Recycled content	Flyash and slag are the major components of this product; recycled aggregate is also compatible
Cost	The cost of this product is about the same as a standard concrete paver
Geographic/regional/ market availability	Available from limited suppliers, but can be sourced within Victoria

Table A11.2: Supplementary Indicators

Indicator	Information
Water usage performance	Savings of 30-40% during manufacturing process
Pollutants (other than greenhouse gas):	Sodium silicate used during the process is toxic.
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Same strength profile as 100% OPC Increased fire, chemical and salt resistance No training or qualifications are required to lay this type of concrete

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product optimise the use of industrial waste?

b) Is the waste sourced locally?

c) Does the product use glass as a sand replacement?

d) Does the product manufacture process use recycled water or harvested rainwater?

e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

g) Can the product use alternative sustainable aggregates?

A12 Geopolymer Cement

1. BACKGROUND

Geopolymer cement does not contain any Ordinary Portland Cement (OPC). Geopolymers are a type of inorganic polymer that can be formed at room temperature by using industrial waste or by-products (fly ash from power generation and slag waste materials from iron and metal production) as source materials to form a solid binder that looks like and performs a similar function to OPC.

Geopolymer binder can be used in a cement mix to replace or partially replace Ordinary Portland cement, resulting in a reduction in the embodied carbon in the final concrete product.

Natural materials like kaolinite and clays could be used as an alternative to the industrial waste; however this would increase the use of the sodium silicate which is toxic and environmentally damaging.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for Geopolymer Cement.

Table A12.1: Core Indicators

Indicator	Information
Embodied Carbon	Embodied carbon in geopolymer cements is approximately 40% lower than OPC
Recycled content	Fly ash and slag is the major component of this product, recycled aggregate is also compatible
Cost	15-20% higher than OPC
Geographic/regional/ market availability	Available from limited suppliers, but can be sourced within Victoria

Table A12.2: Supplementary Indicators

Indicator	Information
Water usage performance	Savings of 30-40% during manufacturing process
Pollutants (other than greenhouse gas):	Sodium silicate used during the process is toxic.
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Same strength profile as 100% OPC Increased fire, chemical and salt resistance No training or qualifications are required to lay this type of concrete

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product optimise the use of industrial waste?

b) Is the waste sourced locally?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

f) Can the product use alternative sustainable aggregates?

A13 Glass-Fibre Reinforced Polymer

1. BACKGROUND

GFR concrete is a concrete mix that uses alkali-resistant glass fibres in a concrete mix in place of reinforcing steel or rebar. Essentially there are two types of GFR concrete

(i) Small diameter fibres are added to the concrete mix and become part of the matrix. This type is used for pipe manufacture and a wide range of non-structural, architectural and building applications

(ii) Larger diameter bars are used as a substitute for conventional steel reinforcing. Currently there is no Australian Standard covering the structural design of concrete members using GFR bars, however it is an emerging and growing area

GFR concrete has been used as an alternative to steel for many years throughout the United Kingdom, and more recently elsewhere in the world.

GFR offers a number of benefits over traditional steel reinforcements including that it does not corrode in saline or high chemical environments.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for Glass Fibre Reinforcement

Table A13.1: Core Indicators

Indicator	Information
Embodied Carbon	Embodied carbon in GFR concrete is approximately 90% lower than in steel reinforced concrete
Recycled content	No recycled content
Cost	GFRP is a quarter of the weight of steel rebar and offers significant savings in transportation and installation The initial cost is significantly higher
Geographic/regional/ market availability	Available within Australia

Table A13.2: Supplementary Indicators

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Information not available
Reusability/Adaptability/ Recyclability:	Not recyclable
Practical applicability:	This product can be used in a number of applications as an alternative to steel reinforcement. Specialist advice is required for structural applications. Currently the most beneficial use is in highly corrosive areas. In these applications the product provides an extended lifetime of the structure and this can be taken into account in assessments.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Can the supplier show that the product has a history of successful use and conforms to international standards?

b) Does the product manufacture process use recycled water or harvested rainwater?

c) Does the supplier have an environmental management system?

d) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

e) Is the manufacturing process efficient?

f) Is the product manufactured within Australia or Victoria?

g) Does the transportation of the material from the factory to the site significantly impact the environmental performance?

A14 Manufactured Sand

1. BACKGROUND

Manufactured sand is made by reprocessing waste material generated through the production of course aggregates at quarries. The waste material is generally finer than 5mm, and with variable properties. Production of manufactured sand from this waste material generally involves crushing, screening and possibly washing

Manufactured sand is defined as a purpose made crushed fine aggregate produced from a suitable source material, and is meant to replace a proportion of natural sand within the mix.

Research by the concrete and extractive industries has shown that, provided the material is appropriately processed and selected from suitable materials, a significant proportion of naturally-extracted sand can be replaced by manufactured sand, while still meeting high-quality concrete specifications.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for Manufactured Sand.

Table A14.1: Core Indicators

Indicator	Information
Embodied Carbon	Actual data is not currently available, however embodied energy is reduced as the manufactured sand is a waste product from aggregate quarrying.
Recycled content	100% recycled content
Cost	A cost benefit exists where travel distances are comparable with those for virgin materials
Geographic/regional/ market availability	Reasonably available product, available in regional Victoria.

Table A14.2: Supplementary Indicators

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	No difference to natural sand
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Manufactured sand can be used for a proportion of the sand mix for all applications

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Is the supplier of manufactured sand a local recycler?

b) Does the product manufacture process use recycled water or harvested rainwater?

c) Does the supplier have an environmental management system?

d) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

e) Is the material tried and tested?

f) Are the contaminant levels suitable?

A15 Permeable Interlocking Concrete Pavers (Picp)

1. BACKGROUND

Permeable interlocking concrete pavers (PICP) provide a sustainable alternative to concrete pavers. PICP are designed with gaps/spaces between individual interlocking pavers facilitate infiltration. The voids between the pavers are filled with a uniform 2-5 mm aggregate to facilitate rapid infiltration of rainfall. The same aggregate can be used as a bedding material for the pavers.

There are three key levels of infiltration which can be designed with PICP:

Full infiltration: all the water infiltrates the subgrade

Partial Infiltration: some water infiltrates the subgrade and some water is removed by a discharge pipe

No infiltration: water is carried through the paver to assist with drainage, but no water infiltrates the subgrade. All water is removed through a discharge pipe

Permeable pavements (including PICP) achieve reductions in the following areas:

Rainfall runoff from pavement surfaces

The size or need for rainwater retention facilities in roadworks by using the pavement itself for retention. This improves land use.

Downstream flooding.

To recharge and maintain aquifers and the natural groundwater.

To trap pollutants that would otherwise contaminate groundwater or drainage systems.

This product can be used for carparks, public areas with pedestrian traffic, tree surrounds, roads and roadside parking, paved areas

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for PICP.

Table A15.1: Core Indicators

Indicator	Information
Embodied Carbon	There is a reduction of approximately 50% in embodied carbon when using permeable paver instead of a conventional paver.
Recycled content	Blended cement (slag and fly ash) can be used to design the pavers Up to 40% slag and 20% fly ash
Cost	Although the up-front costs of PICP are significantly higher than asphalt or concrete pavers, the whole of life costs are expected to be lower. Factors contributing to this include the reduction or elimination of sub-surface drainage infrastructure
Geographic/regional/ market availability	Readily available in regional Victoria

Table A15.2: Supplementary Indicators

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Water usage performance</td><td>The water performance is dependent on the system selected. For example, a superior system would function as a closed loop and use the water captured in the detention system on or around the site. Other systems may only filter and capture pollutants before discharge to the stormwater system
Porous pavements also assist with flood control and run-off</td></tr>
<tr><td>Pollutants (other than greenhouse gas):</td><td>Reduction in the amount of pollutants entering the water system
Reduction in atmospheric pollutants if blended cement is used</td></tr>
<tr><td>Reusability/Adaptability/ Recyclability:</td><td>100% recyclable product (as are standard concrete pavers)</td></tr>
<tr><td>Practical applicability:</td><td>PICP can generally be used in all applications concrete pavers are commonly used:
<table>
<tr><th>Common use for concrete pavers</th><th>PICP suitable?</th><th>Examples</th></tr>
<tr><td>General road paving</td><td>Yes</td><td></td></tr>
<tr><td>High traffic road paving</td><td>No</td><td>n/a</td></tr>
<tr><td>Parking areas and hardstand</td><td>Yes</td><td>Used at Sydney Olympic Park</td></tr>
<tr><td>Footpaths</td><td>Yes</td><td>Used at Sydney Olympic Park</td></tr>
</table>
</td></tr>
</table>

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use recycled or reclaimed asphalt pavement?

b) Is the cement a blended version, i.e. optimising use of waste material?

c) Does the product use glass as a sand replacement?

d) Does the product manufacture process use recycled water or harvested rainwater?

e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A16 Polymer Injection – Reinforcing Steel

1. BACKGROUND

Polymer Injection Technology is a new, patented process, which partially substitutes the use of coke with polymers, including rubber, as an alternate carbon injectant to produce foaming slag Electric Arc Furnace (EAF) Steel.

This innovation offers an opportunity to improve steel cost efficiency while having a positive impact on the environment through energy savings and recycling polymers. Polymer injection of a rubber sourced from used vehicle tyres is now in commercial use at least two EAF facilities in Sydney and Melbourne.

Reinforcing steel manufactured using polymer injection technology has been included in the Green Building Council of Australia's GreenStar Scheme.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for polymer injection technology.

Table A16.1: Core Indicators

Indicator	Information
Embodied Carbon	Data has not yet been quantified for this material; however suppliers report a decrease in electricity use and heat requirements which would result in a reduction of embodied carbon.
Recycled content	Potential to recycle more than 285,000 used passenger tyres per year Recycled steel is used during the process (up to 60%)
Cost	Reduction in cost
Geographic/regional/ market availability	Available in Melbourne by One Steel

Table A16.2: Supplementary Indicators

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Reduced NO_X SO_X and CO emissions
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	This product can be used for all applications where regular reinforcing steel is used

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the supplier use recycled steel?

b) Does the product manufacture process use recycled water or harvested rainwater?

c) Does the supplier have an environmental management system?

d) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

e) Is the manufacturing process efficient?

f) Is the product manufactured within Australia or Victoria?

g) Does the transportation of the material from the factory to the site significantly impact the environmental performance?

A17 PVC-O Pipes

1. BACKGROUND

PVC-O pipes use the same input material as standard PVC pipes but during the manufacturing process, the pipe is expanded in the circumferential and longitudinal directions, therefore orienting the molecular structure in both the hoop and longitudinal directions.

This system produces a pipe with superior strength and compressive performance, while reducing the thickness of the pipe walls and the weight of the finished product.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for PVC-O pipe

Table A17.1: Core Indicators

Indicator	Information
Embodied Carbon	Embodied carbon in PVC-O pipe is slightly higher per kg of finished product, however less of the material is required for every metre of pipe required. When measured over pipe length, the embodied energy in PVC-O pipe is lower than in standard PVC pipe.
Recycled content	Can potentially use reprocessable PVC for its manufacture Most material is virgin plastic
Cost	N/A dependent on required pipe Some suppliers have stated that operational costs would be reduced because of the decreased flow resistance (increased internal diameter) and subsequent lower pumping costs. The pipe also has an improved corrosion resistance (longer-life and no corrosion protection required)
Geographic/regional/ market availability	Available in regional Victoria from local suppliers Current suppliers to the IDM Group supply this product

Table A17.2: Supplementary Indicators

Indicator	Information
Water usage performance	Improved flow capacity due to thinner walls (larger internal diameter) and smoother surfacing (71.25 kL/t of water saved)
Pollutants (other than greenhouse gas):	Information not available. (Pollutants producing PVC are not available?)
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Wide application wherever PVC pipes are currently used

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product manufacture process use recycled water or harvested rainwater?

b) Does the supplier have an environmental management system?

c) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

d) What is the quantity of recycled plastic used in the product

e) Is the product manufactured locally

f) What is the transport impact of the manufacture and delivery?

A18 Reclaimed/Recycled Aggregate Pavement

1. BACKGROUND

Recycled or Reclaimed Asphalt Pavement (RAP) consists of excavated asphalt pavement which is crushed and screened to suit different grading requirements. Asphalt containing RAP is produced by combining the recycled aggregate and binder with virgin aggregate and a new binder.

It is currently acceptable in most states of Australia to include a prescribed proportion of RAP within asphalt mix (generally between 10-30%). The amount of RAP used within a mix is relative to the type of binder required, for example, for up to 15% RAP by weight of total mix (low RAP), no change in binder grade is required, but for 16-25% RAP, by weight of total mix (intermediate RAP content) a lower binder grade (softer binder) is required (refer to the VicRoads spec 407? HMA).

The level of RAP used in HMA is restricted to 50% due to maximum heat capacity and emissions. Warm Mix Asphalt, which is processed at a much lower temperature, could potentially use much higher amounts of RAP.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for RAP.

Table A18.1: Core Indicators

Indicator	Information
Embodied Carbon	Embodied energy in RAP is approximately 46% lower than in equivalent quarry products
Recycled content	100% recycled product Requires some reprocessing The binder on the RAP is reactivated by the heat from the virgin aggregate during mixing, therefore the amount of bitumen binder can be reduced.
Cost	Assuming that the RAP is sourced locally there is a reduction in cost
Geographic/regional/ market availability	Commonly available Where possible, on-site RAP should be used before sourcing externally

Table A18.2: Supplementary Indicators

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Water usage performance</td><td>Significant amount of water from the extraction of virgin material is saved
There was no information available regarding the reprocessing</td></tr>
<tr><td>Pollutants (other than greenhouse gas):</td><td>Reduction in pollutants caused through extraction</td></tr>
<tr><td>Reusability/Adaptability/ Recyclability:</td><td>100% recyclable</td></tr>
<tr><td>Practical applicability:</td><td>RAP can generally be used in all applications HMA is commonly used.
RAP mixes age more slowly and are more resistant to the action of water than conventional mixes
<table>
<tr><th>Common use for HMA</th><th>RAP suitable</th></tr>
<tr><td>General road paving</td><td>Yes</td></tr>
<tr><td>High traffic road paving</td><td>Yes</td></tr>
</table></td></tr>
</table>

Indicator	Information		
	Parking areas and hardstand	Yes	
	Footpaths	Yes	

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use glass as a sand replacement?

b) Does the product use industrial waste as ingredient replacement (e.g. fly ash as filler)?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

f) Is the product manufactured close to the site?

g) Are the components of the product transported significant distances?

A19 Recycled Glass (Rock Replacement)

1. BACKGROUND

Crushed Glass can potentially be used within pavements and concrete as an alternative to gravel and natural aggregates.

The use of this material gives a number of benefits:

Reuse of mixed coloured glass that cannot be recycled into new glass bottles and containers

Conservation of natural resources

Reduced carbon impact

Maintained long-term performance of asphalt or concrete.
The use of glass as a rock replacement in asphalt is sometimes called 'Glassphalt' and can be installed using the same equipment and procedures as conventional asphalt. The grading, cleaning and mixing of this material is essential to ensure performance.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for recycled steel.

Table A19.1: Core Indicators

Indicator	Information
Embodied Carbon	Embodied carbon in recycled glass is approximately 30% less than using virgin materials
Recycled content	100% recycled
Cost	Reduction in cost, especially if Council are using the materials collected through their municipal waste collection system Long whole of life cost
Geographic/regional/ market availability	This product would be readily available from any recycling centre

Table A19.2: Supplementary Indicators

Indicator	Information
Water usage performance	N/A information not available
Pollutants (other than greenhouse gas):	Reduction in pollution compared with natural aggregates because extraction is not required The pollution is still relatively high because of the high amount of reprocessing required
Reusability/Adaptability/ Recyclability:	Recyclable within the asphalt or concrete mix
Practical applicability:	The use of recycled glass in aggregates is not widely accepted within Australia, however, in the USA and UK it has been used for the last couple of decades. Recycled glass can be used in the following applications: low-medium traffic roads, concrete, asphalt (pedestrian), parking areas etc.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Is this a local supplier

b) Do the landfill levies paid by Council regarding their waste compensate for any additional cost?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

f) Is the material tried and tested?

g) Are the contaminant levels suitable?

A20 Recycled Gravel/Reclaimed Aggregates

1. BACKGROUND

Have been proven to be practical for low-strength concretes, and, to a limited extent, for some structural-grade concrete. They can also be used as a component of bedding or backfill.

The aggregates can be reclaimed from the concrete using a number of technologies, with a requirement to wash the aggregates where a clean single size aggregate is required. The water may or may not be reclaimed, and the aggregates are screened for later use, either stockpiled on site, or transported to the new project site.

Positive benefits include:

The amount of material going to land fill is reduced.

Aggregates from selected materials and industrial by-products may be used economically in concrete and as road construction materials.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for recycled aggregate.

Table A20.1: Core Indicators

Indicator	Information
Embodied Carbon	Embodied carbon in recycled gravels is considerably lower than virgin aggregates however actual data has not been found.
Recycled content	100% recycled content
Cost	On-site waste can be used Can purchase from supplier but the transportation distances should be kept low to maintain profitability
Geographic/regional/ market availability	Available in regional Victoria Very common product

Table A20.2: Supplementary Indicators

Indicator	Information
Water usage performance	0.88 KL/t of water is saved by avoiding extraction
Pollutants (other than greenhouse gas):	Information not available
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Recycled aggregate maintains its properties throughout the reclamation process and can therefore be used for the same applications as the virgin material

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Is this a local supplier

b) Do the landfill levies paid by Council regarding their waste compensate for any additional cost?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

f) Is the material tried and tested?

g) Are the contaminant levels suitable?

A21 Recycled Plastic Pipes (Hdpe)

1. BACKGROUND

Recycled HDPE Pipes are made from 100% recycled plastic bottles and are now widely used for civil, agricultural and forestry applications.

This product has been tested, rated and approved by VicRoads (2009) for use under public roads in Victoria, and is certified to AS/NZS 1462.22:1997 and AS/NZS 2566.1:1998

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for recycled HDPE pipe

Table A21.1: Core Indicators

Indicator	Information
Embodied Carbon	Embodied carbon in recycled HDPE is 90% lower than in virgin PVC piping.
Recycled content	100% recycled content HDPE obtained from recycling plastic bottles is a readily available feedstock
Cost	The fully installed/life-cycle cost is lower than competitors The product is 25% cheaper to produce than PVC pipes
Geographic/regional/ market availability	Current supplier for some Councils within the IDM Group Readily available

Table A21.2: Supplementary Indicators

Indicator	Information
Water usage performance	N/A
Pollutants (other than greenhouse gas):	N/A
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Recycled HDPE pipes can generally be used in all applications that PVC pipes are used.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Is feedstock for the recycled pipe sourced locally?

b) Is the product manufactured locally?

c) What is the transport impact of the manufacture and delivery?

d) Does the product manufacture process use recycled water or harvested rainwater?

e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A22 Recycled Steel

1. BACKGROUND

Steel is often recycled by using magnets to separate the steel from other metals. It is then melted and reshaped for a new application.

There are a number of key benefits associated with recycling steel for reuse including:

Every tonne of recycled steel saves 1131kg of iron ore, 633kg of coal and 54kg of limestone

Avoid air and water pollution

Save landfill space, as steel can be recycled indefinitely

Conservation of energy

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for recycled steel.

Table A22.1: Core Indicators

Indicator	Information
Embodied Carbon	Recycled steel has approximately 15-20% less embodied carbon than virgin steel
Recycled content	100% recycled
Cost	Significant cost savings
Geographic/regional/ market availability	This is a very common product, most steel contains recycled content

Table A22.2: Supplementary Indicators

Indicator	Information
Water usage performance	40% reduction in water use 76% reduction in water pollution
Pollutants (other than greenhouse gas):	86% reduction in air pollution 76% reduction in water pollution
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Recycled steel demonstrates the same properties as virgin steel

Victorian Local Sustainability Accord
Sustainability Fund Victoria

pitt&sherry

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) What is the quantity of recycled steel in the product?

b) What have been the transportation distances for the feedstock?

c) Does the product manufacture process use recycled water or harvested rainwater?

d) Does the supplier have an environmental management system?

e) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A23 Recycled Timber

1. BACKGROUND

Recycled timber is timber that has been reclaimed from demolished buildings, bridges, and other structures. In contrast to other construction materials, timber can be reused without requirement for remanufacture. However, it is possible to re-mill or re-finish, improving the physical appearance. Widespread adoption of recycled timber is still constrained by a few limitations in regards to quality and strength. In the construction industry it is often perceived as quicker and easier for the builder to use 'new' wood instead of spending the time and money to acquire the exact sizes and types of recycled timbers needed for a specific construction.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for recycled timber.

Table A23.1: Core Indicators

Indicator	Information
Embodied Carbon	The amount of embodied energy will vary, depending on the original application and the demolition requirements, as well as transport requirements. However, it would generally be lower than for virgin timber.
Recycled content	Recycled timber utilises 100% recycled materials
Cost	Costs for recycled timber vary widely, depending on the type of timber and the intended use. It is however, generally cheaper than the virgin timber equivalent.
Geographic/regional/ market availability	Available in regional Victoria

Table A23.2: Supplementary Indicators

Indicator	Information
Water usage performance	No water is used in timber reuse/recycling (unless the product is retreated).
Pollutants (other than greenhouse gas):	No pollutants are emitted in timber reuse/recycling (unless the product is retreated).
Reusability/Adaptability/ Recyclability:	Timber is 100% recyclable
Practical applicability:	Recycled timber is useful for all applications virgin timber is used; however, the costs for recycled timber vary widely, depending on the type of timber and the intended use.

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product require any further treatment?

b) Is the product suitable for the application?

c) Where was this timber 'rescued' from?

d) What is the transport impact of the product?

e) What level of treatment has been completed on the timber to prepare it for re-sale?

f) Does the supplier have an environmental management system?

g) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

A24 Resin Bound Porous Pavement

1. BACKGROUND

Resin Bound Porous Pavement (RBPP) is an alternative 'water smart' pavement system that can generally be used for pedestrian and low-medium traffic areas. By weight, RBPP consists of 95% natural stone, recycled stone or recycled glass and 5% resin.

This primary purpose of this product is to provide a water saving alternative to traditional asphalt pavements. Resin bound porous pavement allows water to seep through the resin bound aggregate into a free draining structural pavement layer (that also traps contaminants and pollutants) and then either into the stormwater system, a detention system or to the natural soil beneath.

Porous pavement achieves benefits in the following areas:

Reduces rainfall runoff from pavement surfaces

Reduces the size or need for rainwater retention facilities in roadworks by using the pavement itself for retention. This reduces land use.

Reduces downstream flooding.

Recharges and maintains aquifers and the natural groundwater.

Traps pollutants that would otherwise contaminate groundwater or drainage systems.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for RBPP.

Table A24.1: Core Indicators

Indicator	Information
Embodied Carbon	Whilst specific data is not currently available, one study concludes that approximately 50% saving in embodied carbon when a permeable pavement is used instead of a conventionally drained pavement
Recycled content	Can make use of recycled stone/aggregate/glass from on-site or off
Cost	Increase in initial cost but the whole of life is better
Geographic/regional/ market availability	This is a widely available product

Table A24.2: Supplementary Indicators

Indicator	Information
Water usage performance	The water performance is dependent on the system selected. For example, a superior system would function as a closed loop and use the water captured in the detention system on or around the site. A lesser system filters and captures pollutants and discharges the water to the stormwater system Regardless of the system, porous pavement assists with flood control and run-off control
Pollutants (other than greenhouse gas):	Reduction in the amount of pollutants entering the water system
Reusability/Adaptability/ Recyclability:	This material could potentially be recycled for use as Recycled aggregate

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Practical applicability:</td><td>RBPP can be used with limited applications.
This product has a life-span of approximately 20 years if properly maintained (cleaned to avoid clogging)
<table>
<tr><th>Common use for HMA</th><th>RBPP suitable?</th><th>Examples</th></tr>
<tr><td>General road paving</td><td>No</td><td>n/a</td></tr>
<tr><td>High traffic road paving</td><td>No</td><td>n/a</td></tr>
<tr><td>Parking areas and hardstand</td><td>Yes</td><td></td></tr>
<tr><td>Footpaths</td><td>Yes</td><td></td></tr>
</table>
</td></tr>
</table>

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use recycled or reclaimed asphalt pavement?

b) Does the product manufacture process use recycled water or harvested rainwater?

c) Does the supplier have an environmental management system?

d) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

e) Is the resin produced from a sustainable source?

f) Is the chosen aggregate sourced locally?

g) Is the product manufactured close to the site?

h) What is the transport impact of the products components?

A25 Resin Bound Permeable Pavers (Rbpp)

1. BACKGROUND

Resin Bound Porous Pavement (RBPP) is an alternative 'water smart' pavement system that can generally be used for pedestrian and low-medium traffic areas. This primary purpose of this product is to provide a water saving alternative to traditional asphalt pavements. Resin bound porous pavement allows water to seep through the resin and the contaminant catching engineered soils, and either into the stormwater system, a detention system or to the natural soil beneath.

Porous pavement achieves reductions in the following areas:

Rainfall runoff from pavement surfaces

The size or need for rainwater retention facilities in roadwork's by using the pavement itself for retention. This improves land use.

Downstream flooding.

To recharge and maintain aquifers and the natural groundwater.

To trap pollutants that would otherwise contaminate groundwater or drainage systems.

Typically porous pavers need to be cleaned periodically, by mechanical vacuum. Frequency of cleaning is dependent on the contaminant profile of the area of installation. Typically, pavers in a household installation may only need cleaning each 10 years

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for porous pavers.

Table A25.1: Core Indicators

Indicator	Information
Embodied Carbon	Whilst specific data is not currently available, one study concludes that approximately 50% saving in embodied carbon when a permeable pavement is used instead of a conventionally drained pavement
Recycled content	Can make use of recycled stone/aggregate/glass from on-site or off
Cost	Increase in initial cost but the whole of life is better
Geographic/regional/ market availability	This is a widely available product

Table A25.2: Supplementary Indicators

Indicator	Information
Water usage performance	The water performance is dependent on the system selected. For example, a superior system would function as a closed loop and use the water captured in the detention system on or around the site. A lesser system filters and captures pollutants and discharges the water to the stormwater system Regardless of the system, porous pavement assists with flood control and run-off control
Pollutants (other than greenhouse gas):	Reduction in the amount of pollutants entering the water system
Reusability/Adaptability/ Recyclability:	This material could potentially be recycled for use as Recycled aggregate

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Practical applicability:</td><td>RBPP can be used with limited applications.
This product has a life-span of approximately 20 years if properly maintained (cleaned to avoid clogging)

<table>
<tr><th>Common use for stone pavers</th><th>RBPP suitable</th></tr>
<tr><td>General road paving</td><td>No</td></tr>
<tr><td>High traffic road paving</td><td>No</td></tr>
<tr><td>Parking areas and hardstand</td><td>Yes</td></tr>
<tr><td>Footpaths</td><td>Yes</td></tr>
</table>
</td></tr>
</table>

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use recycled or reclaimed asphalt pavement?

b) Does the product manufacture process use recycled water or harvested rainwater?

c) Does the supplier have an environmental management system?

d) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

e) Is the resin produced from a sustainable source?

f) Is the chosen aggregate sourced locally?

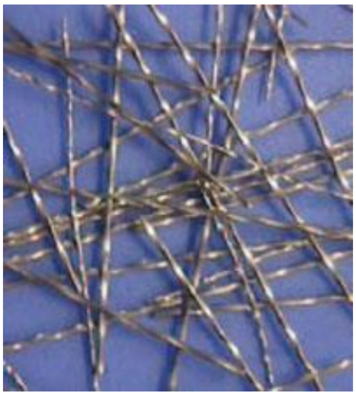
g) Is the transport impact of the components significant?

A26 Twisted Steel Fibre Reinforcement

1. BACKGROUND

Twisted Steel Fibre Reinforcement, also known as Torex fibre, is toothpick sized, coated (galvanised) metallic wire that has been twisted into a helix shape.

Twisted Steel Fibres



(*National Collegiate Inventors and Innovators Alliance, 2012*)

When millions of the small fibres are dispersed into concrete, they lock into place, forming a strong matrix that increases the concrete's blast and impact resistance up to five times over traditional concrete (National Collegiate Inventors and Innovators Alliance, 2012).

The density of the steel fibre within the concrete mix is dependent on the nature of the application. Twisted Steel Fibre Reinforcement can be used for the following applications:

• Structural walls	• Beams/columns
• Structural floors	• Shotcrete
• Foundations	• Tunnelling
• Piles/piers	• Paving
• Pre-cast	

The benefits of using Twisted Steel Fibre Reinforcement rather than steel reinforcing bar or mesh for structural reinforcement include: reducing the amount of steel by weight within the concrete, reduced emissions because of reduced transport requirements, improved cost efficiency because of reduced labour time and improved work safety, increased first crack strength, increased crack resistance, increased durability and increased shear strength.

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for polymer injection technology.

Table A26.1: Core Indicators

Indicator	Information
Embodied Carbon	There is no embodied energy data available for this product. There is an improvement associated with construction (70% reduction in steel, 400% reduction in heavy truck diesel fuel emissions because of shipping improvements). However, there is an increase in shipping/transport impact because the product is manufactured outside of Australia. Therefore it is surmised that there would likely be a slight improvement in embodied carbon
Recycled content	Made from 50% recycled steel (minimum, example from one supplier)
Cost	The product's manufacturers claims a 20% reduction in cost due to the elimination of labour associated with rebar-mesh placement along with reduction of waste steel
Geographic/regional/ market availability	This product is manufactured within the USA (Michigan). The product is shipped to storage facilities in each capital city of Australia where it is then shipped to job sites

Table A26.2: Supplementary Indicators

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Reduced NOX SOX and CO pollutants through reduced onsite transport/construction emissions
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	This product can be used for all applications where regular reinforcing steel is used This product can be placed and finished using traditional concrete methods Performance is enhanced because it is galvanised steel (rust resistant), increased first crack strength, increased crack resistance, increased durability, increased shear strength

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the supplier use recycled steel?

b) Does the product manufacture process use recycled water or harvested rainwater?

c) Does the supplier have an environmental management system?

d) How is the product shipped to Australia?

e) What environmental measures are in place during shipping?

f) Where is the product shipped from, to and how is it transported to the job site?

g) Do you think the transport route and method is efficient?

h) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

i) Is the manufacturing process efficient?

A27 Warm Mix Asphalt

1. BACKGROUND

WMA offers significant benefits in comparison to conventional hot mix asphalt road surfacing methods. It can directly replace hot mix asphalt in many applications and is ideal for use on municipal roads, parking areas, footpaths and driveways where community concerns for the environment are most prevalent.

WMA can be produced using two separate methodologies:

Foam mix: Reduces the temperature of the mix, however requires modifications to batch plants

Additive: The inclusion of the additive reduces mixing temperatures. This method can applied at any batch plant already preparing HMA

2. SUSTAINABILITY INFORMATION

The tables below illustrate the sustainability information for WMA.

Table A27.1: Core Indicators

Indicator	Information
Embodied Carbon	Lower embodied carbon (~30%) in production due to WMA being made at lower temperatures
Recycled content	Allows greater quantities of recycled asphalt to be used in the mix
Cost	Application cost is higher than HMA by approximately 20%
Geographic/regional/market availability	Available in regional Victoria Can be transported longer distances than HMA

Table A27.2: Supplementary Indicators

Indicator	Information
Water usage performance	N/A (supplier dependent)
Pollutants (other than greenhouse gas):	Reduced fumes in production of WMA 55% reduction in fine dust 58% reduction of NO_x 80% reduction in SO_x
Supply Chain/Processing	N/A (supplier dependent)
Reusability/Adaptability/ Recyclability:	Both WMA and HMA are 100% recyclable
Practical applicability:	WMA is produced at a much lower temperature which results in more comfortable and safer workplaces Improved productivity through an extended paving season and longer haul distances as WMA is easier to compact at lower temperatures. WMA can generally be used in all applications HMA is commonly used:

Common use for HMA	WMA suitable	Examples
General road paving	Yes	VicRoads approved
High traffic road paving	Yet to be confirmed	n/a
Parking areas and hardstand	Yes	VicRoads approved

Indicator	Information		
	Footpaths	Yes	Successfully applied by a Queensland local Council

3. SUGGESTED SUPPLIER QUESTIONS

To determine potential for additional environmental and sustainability benefits dependent on supplier operations and processes, the following questions should be considered:

a) Does the product use recycled or reclaimed asphalt pavement?

b) Does the product use glass as a sand replacement?

c) Does the product use industrial waste as ingredient replacement (e.g. fly ash as filler)?

d) Does the product manufacture process use recycled water or harvested rainwater?

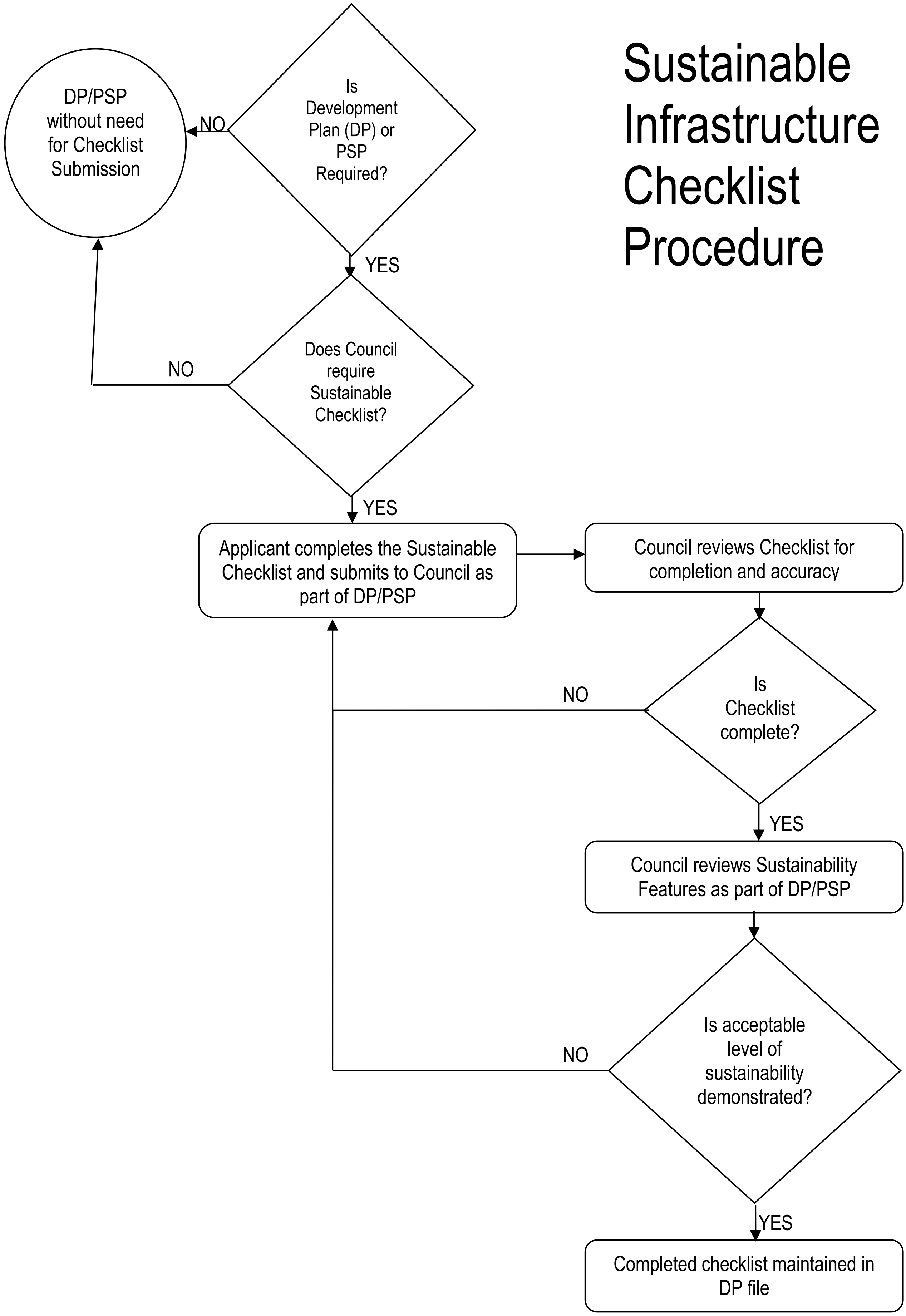
e) Does the supplier have an environmental management system?

f) Does the supplier use alternative energy (e.g. greenpower, biofuels, natural gas, solar)?

g) Does the transportation of the product impact on the product's environmental performance?

APPENDIX B SUSTAINABLE INFRASTRUCTURE CHECKLIST

Sustainable Infrastructure Checklist Procedure



Sustainable Infrastructure Checklist

TRANSPORT	Does the development implement any of the following sustainability measures for footpaths?	Permeable footpath surfaces	
		Separate from road to incorporate WSUD treatments	
		Other:	
		Describe here:	
	Does the development design include pedestrian or cycling oriented infrastructure?	Separate bike lanes or paths	
		Multi use (pedestrians and cycling)	
		Visible/secure all-weather bicycle racks	
		Direct pedestrian linkages to transit stops?	
		Other:	
		Describe here:	
	Does the project include private vehicle use reduction and emission reduction measures?	On-street parking away from pedestrian and cycling paths	
		Car sharing and green travel plan initiatives	
		Carpark sharing	
		Sustainable use of vehicle overhang	
		Smaller car parking spaces	
		Permeable pavement surfaces	
		Other:	
		Describe here:	
	Does the development implement any of the following sustainability measures for roads?	Recycled base/subbase materials	
		Alternative base/subbase materials	
		Warm Mix Asphalt (RAP)	
		Recycled Asphalt Pavement (RAP)	
		Emulsion seals	
		Other:	
		Describe here:	

INTEGRATED WATER MANAGEMENT	Does the development involve any of the following drainage concepts	Retardation Basins and Small Detention Systems	
		Increased infiltration (Wetlands, retention basins, swales and water gardens)	
		WSUD drainage systems	
		Decentralised waste-water treatment (and reuse) systems	
		Other	
		Describe here:	
	Does the development involve any of the following stormwater management concepts?	Natural processes to remove litter, sediment and nutrients	
		Grass or permeable surfaces to reduce run off	
		Stormwater harvesting	
		Recycle water to reduce demand on potable water	
		Other:	
		Describe here:	
	Does the development incorporate any of the following water saving measures?	Low water consumption devices	
		Regular procedures employed to remedy leaks	
		Other:	
		Describe here:	

Sustainable Infrastructure Checklist

MATERIAL RECYCLING AND REUSE	Does the contractor selection process take into account Environmental Performance Assessments?	Describe here:	
	Does the contract documentation specify the reuse and recycling of selected materials?	Describe here:	
	Does the development reuse/recycle any of the following materials from the site?	Aggregates	
		Masonry	
		Timber	
		Other	
		Describe here:	
	Does the development reuse/recycle any of the following materials from another source?	Aggregates.	
		Masonry	
		Timber	
		Other	
		Describe here:	
	Does the development use alternative construction materials which reduce the carbon footprint?	Describe here:	

PUBLIC LIGHTING	Does the development use energy efficient lamps for street lighting or decorative lighting?	T5 linear fluorescent	
		LED	
		Other	
		Describe here:	
	Does the development replace existing lighting with energy efficient lamps?	T5 linear fluorescent	
		LED	
		Other	
		Describe here:	
	Does the development include renewable energy to power landscape elements such as lighting?	Solar energy	
		Other:	
		Describe here:	

Sustainable Infrastructure Checklist

LANDSCAPING AND OPEN SPACE	Does the development preserve, enhance or compensate for site ecology on or off site using the following measures?	Reduce impervious area	
		Increase tree canopy coverage	
		Retain protected trees	
		Plant trees onsite (net increase)	
		Plant trees offsite (net increase)	
		Reuse/retain site topsoil	
		Create park areas	
		Other:	
		Describe here:	
	Does the landscape development reduce carbon footprint using the following measures?	Use alternative materials	
		Reuse or recycle materials	
		New timber products from sustainably managed sources	
		Other:	
		Describe here:	
	Does the development address any of the following social and community measures?	Involve local community	
		A continuing program of community involvement	
		Provide recycling facilities	
		Majority of contractors from local area	
		Other:	
		Describe here:	
GENERAL	Will Post Construction Evaluation be carried out?	Describe here:	
	Does the development have long-term flexibility designed in to allow for changes of use in the future?	Describe here:	
	Does the development seek third party rated green standards or features?	Describe here:	
	Are residents, community stakeholders and end-user groups involved in the planning process?	Describe here:	
	Do any existing Council regulations currently prevent you from implementing more sustainable initiatives for this development?	Describe here:	
	Does the development include sustainability features not addressed in this checklist?	Describe here:	

APPENDIX C CARCON CALCULATION TOOL

Victorian Local Sustainability Accord
Sustainability Fund
Victoria
pitt&sherry

Carbon Calculator

Home

Project

Materials

Fuel and electricity

Default emissions

Results

SLR global environmental solutions

INTRODUCTION

This "Carbon Calculator" has been prepared as a supplement to the IDM Group's Infrastructure Design Manual.
The calculator uses data for embodied carbon that was researched during the preparation of the Green Supplement to the Manual (see Default Emissions).

This data considers the emissions associated with all stages of the life cycle of materials, including extraction, processing and transport.
Emissions factors are also provided for electricity and fuel use.

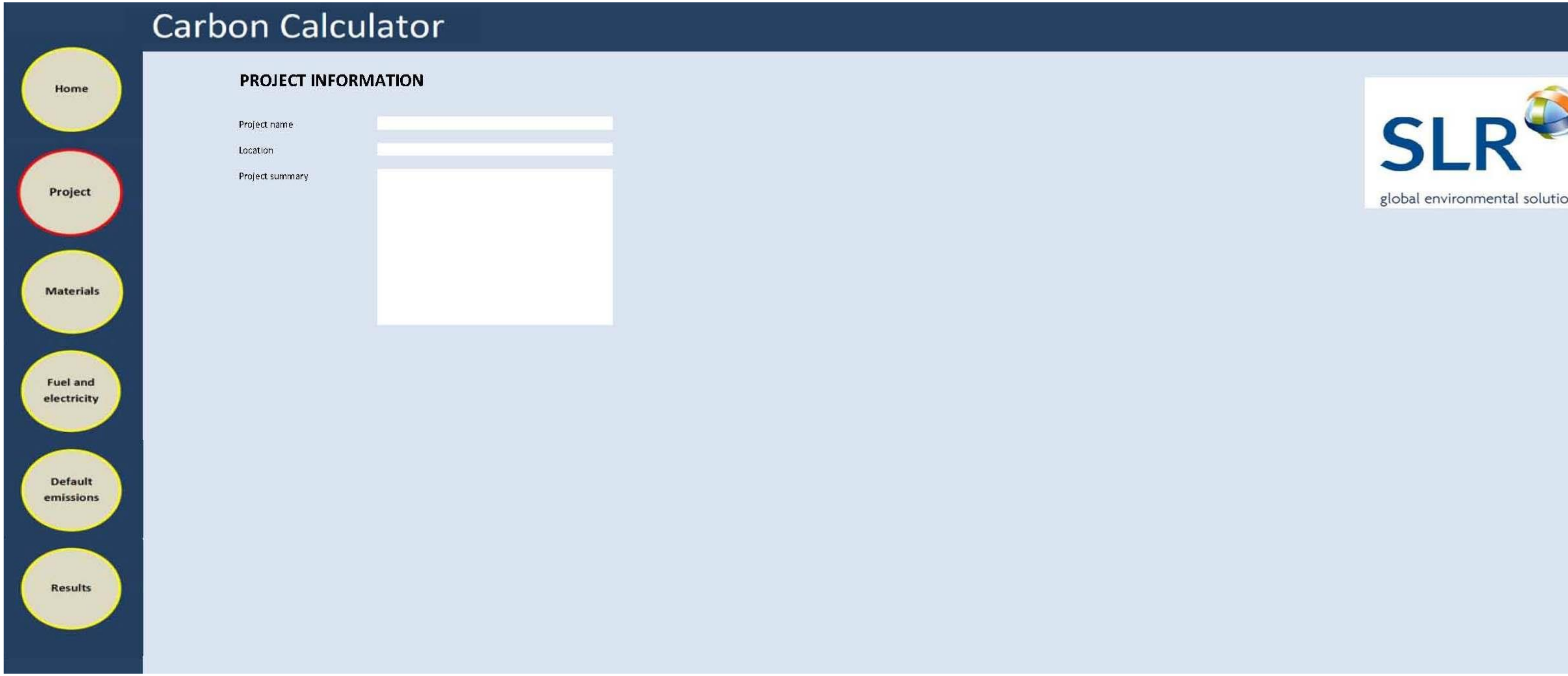
INSTRUCTIONS

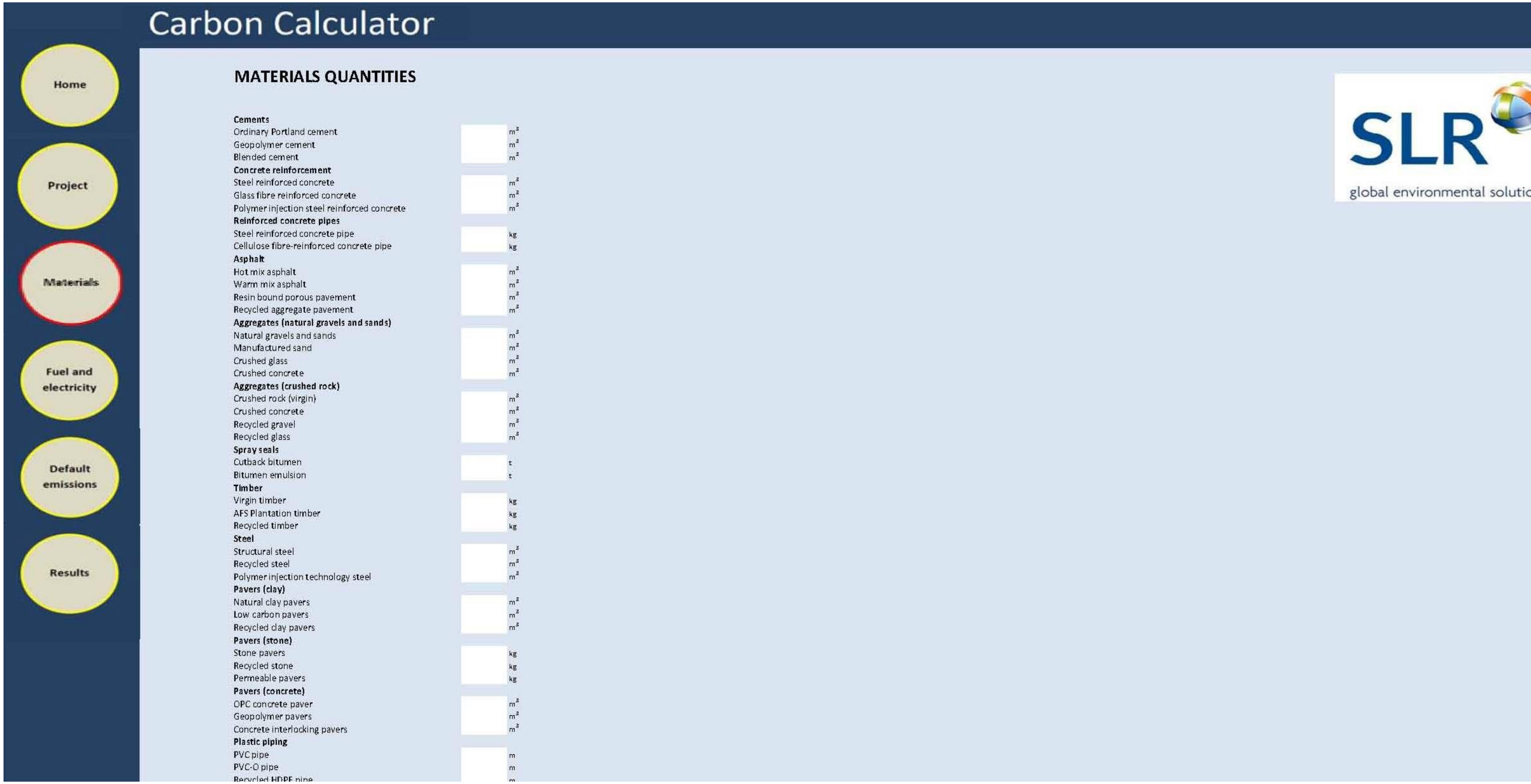
Navigate through the workbook using the tabs on the left of the worksheet.
Enter material amounts in the tab marked "Materials" for all relevant materials. The calculator will determine the corresponding embodied carbon emissions.
Enter fuel and electricity amounts for the project in the tab marked "Fuel and electricity".
The calculator will determine the corresponding emissions (Scope 1 only for fuels, and Scope 2 only for electricity).

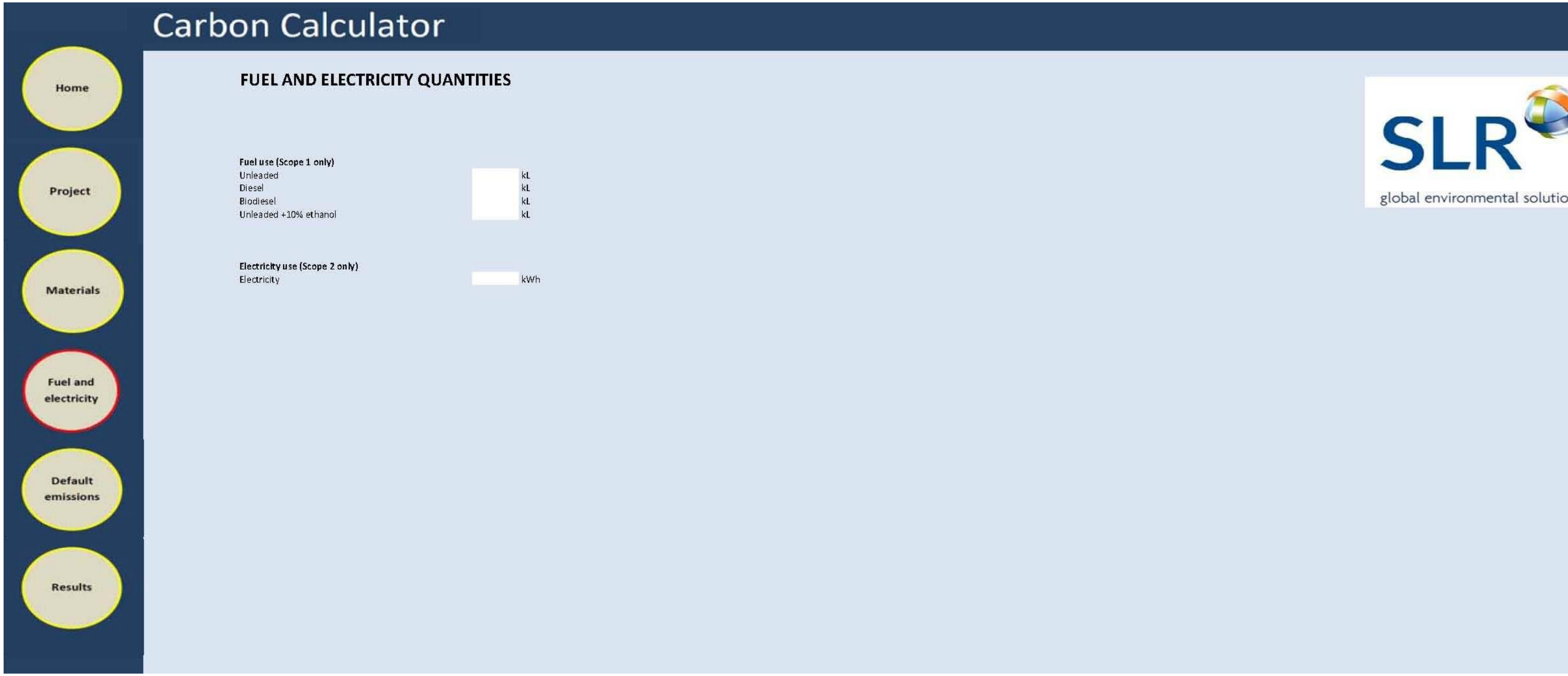
If more up-to-date data becomes available for a given material, this can be worked into the calculator via the "User-defined values" section in the Default Emissions tab.
Simply enter the new data into the space provided. Ensure new data is entered as kgCO2 per unit, and that unused spaces in this column remain blank.

Note: This calculator is for use by member councils of the IDM Group only and may not be reproduced without permission.
The information contained herein is applicable only to operations carried out within Victoria.
Data used in the development of emissions factors was taken from the following sources:

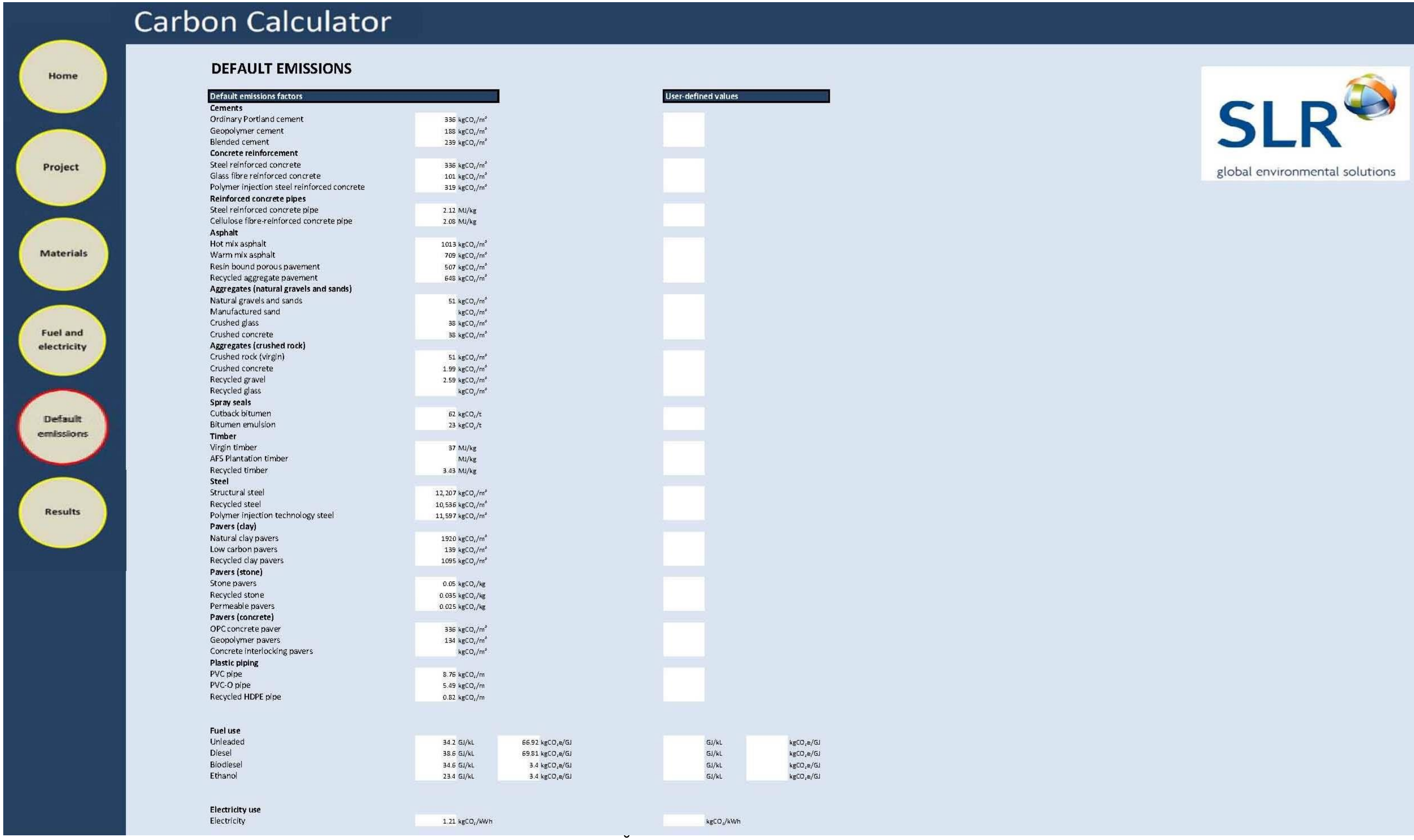
- National Greenhouse Accounts Factors July 2011
- D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings, 2010, Development of an Embodied CO2 Emissions Module for AccuRate Forest & Wood Products Australia
- Benjamin C. McLellan, Ross P. Williams, Janine Lay, Arie van Riessen, Glen D. Corder, 2011, Costs and carbon emissions for Geopolymer pastes in comparison to Ordinary Portland Cement
- EcoBlend, Independent Cement and Lime Pty Ltd, Victoria
- Don Wimpenny, Peter Duxson, Tony Cooper John Provis, Robert Zeuschner, 2011, Fibre reinforced geopolymer concrete products for underground infrastructure, Victorian Science Agenda Investment Fund (and consortia)
- OneSteel, 2010, Building a sustainable future sustainability REPORT 2010
- Prof. Geoff Hammond & Craig Jones, 2011, 'Inventory of Carbon & Energy (ICE)' V2.0, University of Bath
- Cook, I & Knapton, J 2009 'Assessment of embodied carbon in conventional and permeable pavements surfaced with pavers' paper presented at 9th International Conference on Concrete Block Paving.
- ARRB Group January 2009
- Sustainable Aggregates South Australia, 2010. CO2 Emissions Factor Study, ARRB Group SA
- The Energy and Resources Institute, 2004, Sustainable Building Design Manual: Sustainable building design practices, Delhi
- AustRoads, 2008, Bitumen emulsions:Austroads technical report, AustRoads Sydney Australia
- SimaPro 2012
- Net Balance Foundation, 2007, Carbon Emission Life Cycle Assessment of Geopolymer Concrete, Zeobond
- Australian Greenhouse Office, 2004.
- Recycled Plastic Technology Pty Ltd, The Green Pipe website
- Ecobricks Group, ecobricks website, 2012


Carbon Calculator
Home
Project
Materials
Fuel and electricity
Default emissions
Results
PROJECT INFORMATION
Project name
Location
Project summary
SLR
global environmental solutio


Carbon Calculator
Home
Project
Materials
Fuel and electricity
Default emissions
Results
MATERIALS QUANTITIES
SLR
global environmental solutio
Cements
Ordinary Portland cement m^3
Geopolymer cement m^3
Blended cement m^3
Concrete reinforcement
Steel reinforced concrete m^3
Glass fibre reinforced concrete m^3
Polymer injection steel reinforced concrete m^3
Reinforced concrete pipes
Steel reinforced concrete pipe kg
Cellulose fibre-reinforced concrete pipe kg
Asphalt
Hot mix asphalt m^3
Warm mix asphalt m^3
Resin bound porous pavement m^3
Recycled aggregate pavement m^3
Aggregates (natural gravels and sands)
Natural gravels and sands m^3
Manufactured sand m^3
Crushed glass m^3
Crushed concrete m^3
Aggregates (crushed rock)
Crushed rock (virgin) m^3
Crushed concrete m^3
Recycled gravel m^3
Recycled glass m^3
Spray seals
Cutback bitumen t
Bitumen emulsion t
Timber
Virgin timber kg
AFS Plantation timber kg
Recycled timber kg
Steel
Structural steel m^3
Recycled steel m^3
Polymer injection technology steel m^3
Pavers (clay)
Natural clay pavers m^3
Low carbon pavers m^3
Recycled clay pavers m^3
Pavers (stone)
Stone pavers kg
Recycled stone kg
Permeable pavers kg
Pavers (concrete)
OPC concrete paver m^3
Geopolymer pavers m^3
Concrete interlocking pavers m^3
Plastic piping
PVC pipe m
PVC-O pipe m
Recycled HDPE pipe m


Carbon Calculator
Home
Project
Materials
Fuel and electricity
Default emissions
Results
FUEL AND ELECTRICITY QUANTITIES
Fuel use (Scope 1 only)
Unleaded kL
Diesel kL
Biodiesel kL
Unleaded +10% ethanol kL
Electricity use (Scope 2 only)
Electricity kWh
SLR
global environmental solutio

sustainable infrastructure guidelines



Carbon Calculator

Home

Project

Materials

Fuel and electricity

Default emissions

Results

DEFAULT EMISSIONS

global environmental solutions

Default emissions factors		
Cements		
Ordinary Portland cement	336	$kgCO_2/m^3$
Geopolymer cement	188	$kgCO_2/m^3$
Blended cement	239	$kgCO_2/m^3$
Concrete reinforcement		
Steel reinforced concrete	336	$kgCO_2/m^3$
Glass fibre reinforced concrete	101	$kgCO_2/m^3$
Polymer injection steel reinforced concrete	319	$kgCO_2/m^3$
Reinforced concrete pipes		
Steel reinforced concrete pipe	2.12	MJ/kg
Cellulose fibre-reinforced concrete pipe	2.08	MJ/kg
Asphalt		
Hot mix asphalt	1013	$kgCO_2/m^3$
Warm mix asphalt	709	$kgCO_2/m^3$
Resin bound porous pavement	507	$kgCO_2/m^3$
Recycled aggregate pavement	648	$kgCO_2/m^3$
Aggregates (natural gravels and sands)		
Natural gravels and sands	51	$kgCO_2/m^3$
Manufactured sand		$kgCO_2/m^3$
Crushed glass	38	$kgCO_2/m^3$
Crushed concrete	38	$kgCO_2/m^3$
Aggregates (crushed rock)		
Crushed rock (virgin)	51	$kgCO_2/m^3$
Crushed concrete	1.99	$kgCO_2/m^3$
Recycled gravel	2.59	$kgCO_2/m^3$
Recycled glass		$kgCO_2/m^3$
Spray seals		
Cutback bitumen	62	$kgCO_2/t$
Bitumen emulsion	23	$kgCO_2/t$
Timber		
Virgin timber	37	MJ/kg
AFS Plantation timber		MJ/kg
Recycled timber	3.43	MJ/kg
Steel		
Structural steel	12,207	$kgCO_2/m^3$
Recycled steel	10,536	$kgCO_2/m^3$
Polymer injection technology steel	11,597	$kgCO_2/m^3$
Pavers (clay)		
Natural clay pavers	1920	$kgCO_2/m^3$
Low carbon pavers	139	$kgCO_2/m^3$
Recycled clay pavers	1095	$kgCO_2/m^3$
Pavers (stone)		
Stone pavers	0.05	$kgCO_2/kg$
Recycled stone	0.035	$kgCO_2/kg$
Permeable pavers	0.025	$kgCO_2/kg$
Pavers (concrete)		
OPC concrete paver	336	$kgCO_2/m^3$
Geopolymer pavers	134	$kgCO_2/m^3$
Concrete interlocking pavers		$kgCO_2/m^3$
Plastic piping		
PVC pipe	8.76	$kgCO_2/m$
PVC-O pipe	5.49	$kgCO_2/m$
Recycled HDPE pipe	0.82	$kgCO_2/m$

User-defined values

Fuel use	Default				User-defined values	
Unleaded	34.2 GJ/kL		66.92 $kgCO_2e/GJ$		GJ/kL	$kgCO_2e/GJ$
Diesel	38.6 GJ/kL		69.81 $kgCO_2e/GJ$		GJ/kL	$kgCO_2e/GJ$
Biodiesel	34.6 GJ/kL		3.4 $kgCO_2e/GJ$		GJ/kL	$kgCO_2e/GJ$
Ethanol	23.4 GJ/kL		3.4 $kgCO_2e/GJ$		GJ/kL	$kgCO_2e/GJ$

Electricity use	Default	User-defined values
Electricity	1.21 $kgCO_2/kWh$	$kgCO_2/kWh$

sustainable infrastructure guidelines

Carbon Calculator

Home

Project

Materials

Fuel and electricity

Default emissions

Results

RESULTS

Cements		
Ordinary Portland cement	0	$kgCO_2$
Geopolymer cement	0	$kgCO_2$
Blended cement	0	$kgCO_2$
Concrete reinforcement		
Steel reinforced concrete	0	$kgCO_2$
Glass fibre reinforced concrete	0	$kgCO_2$
Polymer injection steel reinforced concrete	0	$kgCO_2$
Reinforced concrete pipes		
Steel reinforced concrete pipe	0	MJ/kg
Cellulose fibre-reinforced concrete pipe	0	MJ/kg
Asphalt		
Hot mix asphalt	0	$kgCO_2$
Warm mix asphalt	0	$kgCO_2$
Resin bound porous pavement	0	$kgCO_2$
Recycled aggregate pavement	0	$kgCO_2$
Aggregates (natural gravels and sands)		
Natural gravels and sands	0	$kgCO_2$
Manufactured sand	0	$kgCO_2$
Crushed glass	0	$kgCO_2$
Crushed concrete	0	$kgCO_2$
Aggregates (crushed rock)		
Crushed rock (virgin)	0	$kgCO_2$
Crushed concrete	0	$kgCO_2$
Recycled gravel	0	$kgCO_2$
Recycled glass	0	$kgCO_2$
Spray seals		
Cutback bitumen	0	$kgCO_2$
Bitumen emulsion	0	$kgCO_2$
Timber		
Virgin timber	0	$kgCO_2$
AFS Plantation timber	0	$kgCO_2$
Recycled timber	0	$kgCO_2$
Steel		
Structural steel	0	$kgCO_2$
Recycled steel	0	$kgCO_2$
Polymer injection technology steel	0	$kgCO_2$
Pavers (clay)		
Natural clay pavers	0	$kgCO_2$
Low carbon pavers	0	$kgCO_2$
Recycled clay pavers	0	$kgCO_2$
Pavers (stone)		
Stone pavers	0	$kgCO_2$
Recycled stone	0	$kgCO_2$
Permeable pavers	0	$kgCO_2$
Pavers (concrete)		
OPC concrete paver	0	$kgCO_2$
Geopolymer pavers	0	$kgCO_2$
Concrete interlocking pavers	0	$kgCO_2$
Plastic piping		
PVC pipe	0	$kgCO_2$
PVC-O pipe	0	$kgCO_2$
Recycled HDPE pipe	0	$kgCO_2$
Fuel use		
Unleaded	0	$kgCO_2$
Diesel	0	$kgCO_2$
Biodiesel	0	$kgCO_2$
Ethanol	0	$kgCO_2$
Electricity use		
Electricity	0	$kgCO_2$

Materials	0	$kgCO_2$
Fuels	0	$kgCO_2$
Electricity	0	$kgCO_2$
Total (kilograms)	0	$kgCO_2$
Total (tonnes)	0	tCO_2

SLR global environmental solutio

APPENDIX D DETAILED ASSESSMENT OF PRODUCT SUSTAINABILITY

APPENDIX D DETAILED ASSESSMENT OF PRODUCT SUSTAINABILITY

D1 Cement

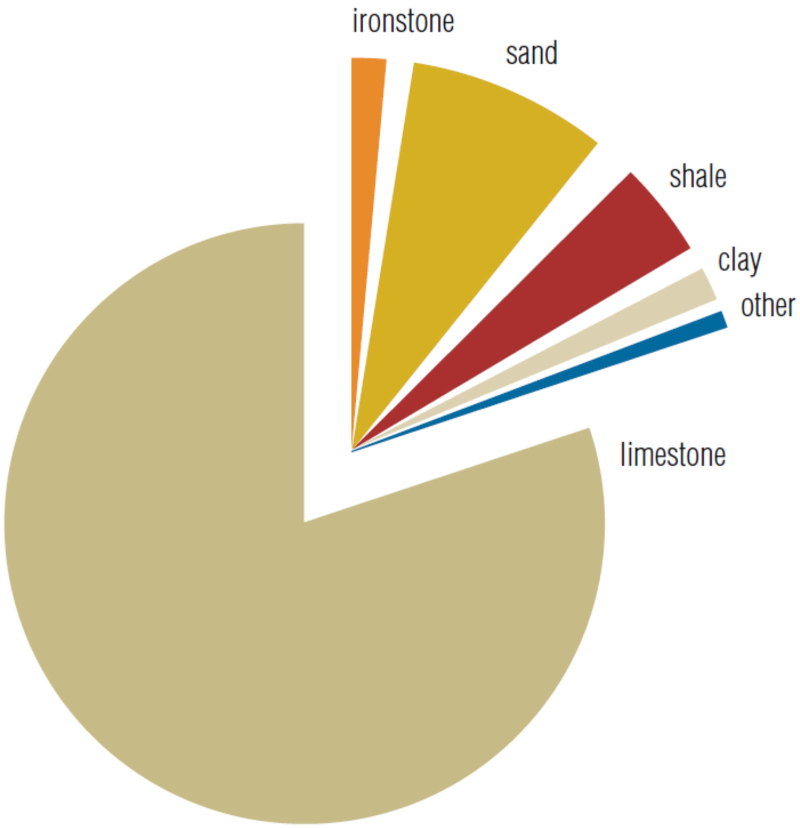
D1.1 General

Concrete is the most commonly used construction material in the world today (Cement Concrete and Aggregates Australia, 2010). According to the Cement Industry Foundation (n.d.), three tonnes of concrete is used per person per year in Australia.

Cement is the binder used in concrete and is generally made from calcium (limestone), silica (sand), aluminium and iron. These raw ingredients are heated in a high-temperature kiln to form a 'clinker'. This pebble-like clinker is combined with gypsum and ground to the grey powder recognised as common cement.

Ordinary Portland cement (OPC) is the most commonly used cement binder and consists of a mixture of calcium carbonate, silica, iron oxide and alumina. The primary raw material used in the production process is limestone, which is the source of the calcium. Other raw materials include clay, shale, sand and ironstone (Cement Concrete and Aggregates Australia, 2010). (See **Figure D1.1**).

Figure D1.1 Raw materials used in the production of Portland cement



(Cement Concrete and Aggregates Australia, 2010).

Sustainability drivers

Although limestone is ubiquitous, has low extraction costs and performs very well as an element of cement, its high energy requirement for transportation and processing (in addition to its high carbon content) makes it problematic as a core ingredient of cement (Ernst von Weizsäcker et al, 2009).

Globally, the production of cement contributes at least 5-7% of CO2 emissions while in Australia, it is estimated that the production of cement accounted for approximately 1.3% of greenhouse gas emissions in 2008 (Benjamin C. McLellan et al).

Research into current and emerging sustainable alternatives to the use of OPC focused on the following materials:

- Geopolymer cement
- Blended cement

Geopolymer

Geopolymers are a type of inorganic polymer formed at room temperature by using industrial waste or by-products as source materials to form a solid binder that looks like and performs a similar function to Ordinary Portland cement (NetBalance 2007).

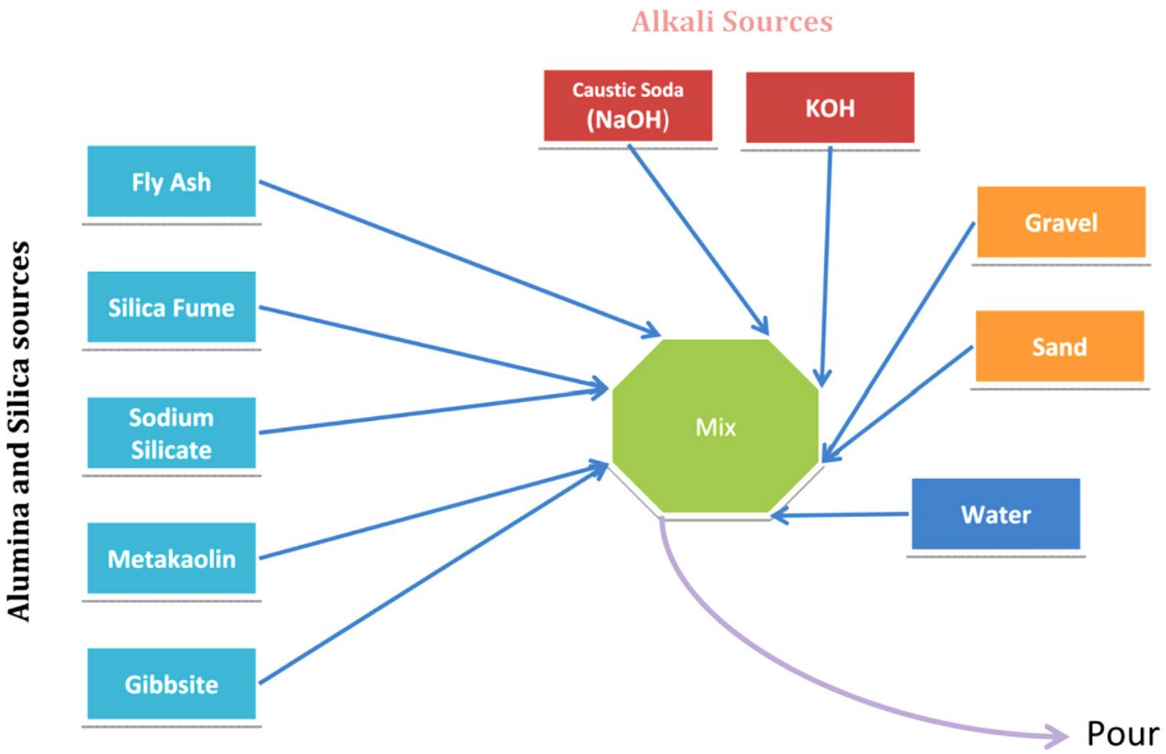
Waste materials suitable for use as the base materials in geopolymer cement include:

- Fly ash and bottom ash (from coal fired power stations)
- Granulated blast-furnace slags
- Some mine wastes
- Other fine materials containing silicon and aluminium in an amorphous form

Geopolymer binder can be used in a cement mix to replace or partially replace Ordinary Portland cement, resulting in a reduction in the embodied carbon in the final concrete product.

For the purpose of this study we based our research on a type of geopolymer cement that contains fly ash plus other additives **(see Figure D1.2).**

Figure D1.2Geopolymer Inputs



(McLellan et al 2011)

The following tables provide some of the key characteristics of Geopolymer cements.

Table D1.1 Core Indicators, Geopolymer Cement

Indicator	Information
Embodied Carbon	Embodied carbon in geopolymer cements is approximately 40% lower than OPC
Recycled content	Fly ash and slag is the major component of this product, recycled aggregate is also compatible
Cost	15-20% higher than OPC
Geographic/regional/ market availability	Available from limited suppliers, but can be sourced within Victoria

Table D1.2 Supplementary Indicators, Geopolymer Cement

Indicator	Information
Water usage performance	Savings of 30-40% during manufacturing process
Pollutants (other than greenhouse gas):	Sodium silicate used during the process is toxic.
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Same strength profile as 100% OPC Increased fire, chemical and salt resistance No training or qualifications are required to lay this type of concrete

Blended cements

Blended cement is manufactured for use in general purpose concrete applications including cement-based products, mortars and grouts (Cement Australia 2011). Blended cements contain Supplementary Cementitious Materials (SCMs) generally sourced from industrial wastes as a replacement for a proportion of the OPC.

The three types of SCMs commonly used in Australia are

- Ground granulated blast-furnace slag (slag)
- Fly ash
- Amorphous silica

By reducing the amount of manufactured cement required in a given concrete mix, the use of SCMs reduces concrete's environmental impact. SCMs also lead to better economic outcomes for concrete construction – being an industrial by-product – they can be procured at a lower cost than that of manufactured cement. (Cement Concrete and Aggregates Australia 2010).

This product is comparable to OPC cement for its performance, and is now used commonly in many infrastructure and construction applications.

The following tables some of the key characteristics of blended cements.

Table D1.3 Core Indicators, Blended Cement

Indicator	Information
Embodied Carbon	SCMs have approximately 40% less embodied energy than OPC
Recycled content	Uses industrial waste (slag/fly ash) General composition is up to 30% SCM with remaining OPC
Cost	Cost is the same as OPC, with some suppliers offering discounts compared with OPC
Geographic/regional/ market availability	The cement mix is available from Port Melbourne and, can be supplied and mixed by any plant. Currently supply to regional Victoria

Table D1.4 Supplementary Indicators, Blended Cement

Indicator	Information
Water usage performance	There is a water-use benefit associated with blended cements. This benefit is dependent on the amount of blended cement used in the mix, and also the type of SCM used Assume up to 15% reduction (best case, using approximately 30% SCM within cement mix)
Pollutants (other than greenhouse gas):	30% reduction in carcinogens and heavy metals
Reusability/Adaptability/ Recyclability:	100% recyclable product as crushed concrete aggregate
Practical applicability:	Extended structural life Reduced maintenance costs Can reduce heat island effects through lighter colour

D1.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D1.5 Core Indicators, Cement

Product	Carbon	Recycled content	Cost	Geographic/regional/ market availability
OPC	0	0	5	5
Geopolymer	4	5	4	3
Blended	4	3	5	5

Table D1.6 Supplementary Indicators, Cement

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/ Adaptability/ Recyclability	Practical applicability
OPC	0	0	5	4
Geopolymer	4	3	5	5
Blended	3	3	5	5

The final weighted scores are shown below.

Table D1.7 Weighted scores, Cement

Material	Weighted Score (out of 100)
OPC	48
Geopolymer	81.5
Blended Cement	84

D1.3 Discussion

Due to the high embodied carbon present in OPC, opportunities exist throughout the construction industry to significantly reduce the embodied carbon in construction projects by considering alternative cement mixes. The two alternatives discussed here; geopolymer cement and blended cements are both available in regional Victoria (blended cement is more so) and suitable for all applications for which OPC is currently used.

With a slightly lower cost than geopolymer cements, and no requirement for batch plant modification, blended cements may currently represent the most attractive alternative to OPC.

D1.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D1.8 Manufacturers, Alternative Cement

Geopolymer Cement	Comments
ZeoBond, *E-Crete*	Geopolymer cement cannot be mixed within a standard plant, the whole concrete mix needs to be purchased through this supplier The concrete can be laid by a conventional concrete crew without additional training Melbourne based company and manufacturing plant
Blended Cement	Comments
Independent Cement, *EcoBlend*	The sales manager stated that this brand of cement can be applied and mixed within standard plants *EcoBlend* is supplied and mixed by some regional Victorian suppliers (e.g. Hansons and Mawsons)
Blue Circle Southern Cement (Boral)	Readily available and mixed in Victoria
Adelaide Brighton Cement	Manufactured in Adelaide but can be supplied to Victoria

The current market for Geopolymer Cement is relatively limited as the product is patented by ZeoBond. However, this product is a Melbourne based company and is available to regional Victoria

Blended cements are readily available throughout Victoria, and are now included in many jurisdictions' specifications and requirements. It is noted that both Hanson and Mawson do not advertise that they have a 'sustainable' alternative to OPC cement available to their customers. Increased demand may result in cheaper prices and a more publicised approach by suppliers.

It is also important to note that blended cements can be mixed into concrete within any standard plant. This promotes competition and does not reduce the opportunity for new entries into the market.

D2 CONCRETE REINFORCEMENT

D2.1 General

While the above section presents cement and cement alternatives, it is also possible to consider other elements in a concrete mix when making decisions based on sustainability principles.

Concrete is the most commonly used construction material in the world today (Sustainable Concrete Materials, Cement Concrete and Aggregates Australia). Concrete production is a major source of greenhouse gas emission, being responsible for up to 7-10% of global CO_2 emissions. This is due to a combination of the sheer volume of concrete produced and the very high temperatures required to create the core "Portland cement" material used in the standard process (Carbon Emission Life-cycle Assessment of Geopolymer Concrete, NetBalance 2007).

This section will consider the alternatives available for reinforced concrete applications.

Reinforced concrete is made of concrete and steel. The steel can be included either as a fibrous additive, or in the form of rods and/or mesh (rebar). For the purpose of this assessment it is assumed that rebar is the most common form, and is therefore considered the base material. The inclusion of steel to concrete gives the following benefits:

- Resistance to the action of water
- Additional structural strength
- Architectural advantages, e.g. shell structures, including tensile strength
- Flexibility in design

Sustainability issues

Most steel products on the market will contain some percentage of recycled steel. The level of inclusion depends largely on the method used for manufacturing the product.

Steel extraction and production is an energy intensive process, especially when using raw materials as the primary feedstock. Most steel products require significant transportation because of the small number of steel production sites across Australia. To give an indication of the energy intensive production process, the transportation only contributes about 2% of the overall carbon impact (Strezov and Herberston 2006).

This section considers Glass Fibre Reinforced Concrete and steel produced with Polymer Injection Technology as alternatives to steel reinforced concrete.

Glass Fibre-reinforced concrete

GFR concrete is a concrete mix that uses alkali-resistant glass fibres in place of reinforcing steel or rebar. Essentially there are two types of GFR concrete:

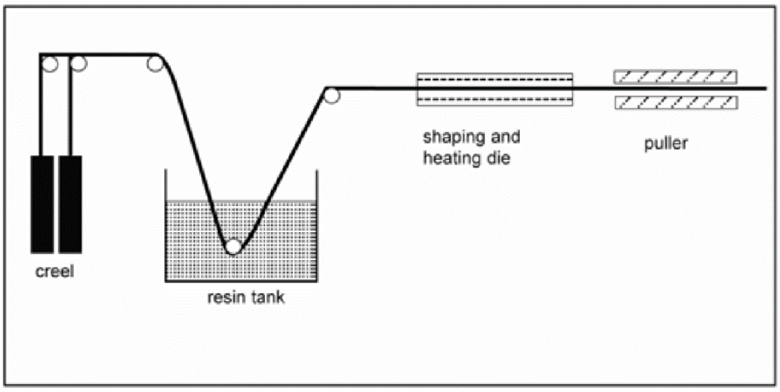
1 Small diameter fibres are added to the concrete mix and become part of the matrix. This type is used for pipe manufacture and a wide range of non-structural, architectural and building applications.

2 Larger diameter bars are used as a substitute for conventional steel reinforcing. Currently there is no Australian Standard covering the structural design of concrete members using GFR bars, however it is an emerging and growing area.

(Concrete Network 2012)

Pultrusion is a common technique for manufacturing continuous lengths of FRP bars that are of constant or nearly constant profile. To make sure there is solid adhesive between the glass and the concrete, a layer of sand is usually added to the outside (ISIS Canada Research Network 2007). This methodology is also confirmed by an article published by Queensland Roads in 2011. The pultrusion process is shown within the below figure **(Figure D2.1** Pultrusion Process) and is indicative of the process used to generate large diameter bars.

Figure D2.1Pultrusion Process



(ISIS Canada Research Network 2007).
GFR offers a number of benefits over traditional steel reinforcements. The main benefits include: it does not corrode in saline or high chemical environments and the carbon impact is significantly lower.

The tables below illustrate the sustainability information for Glass Fibre Reinforcement

Table D2.1 Core Indicators, Glass Fibre Reinforcement

Indicator	Information
Embodied Carbon	Embodied carbon in GFR concrete is approximately 90% lower than in steel reinforced concrete
Recycled content	No recycled content
Cost	GFRP is a quarter of the weight of steel rebar and offers significant savings in transportation and installation The initial cost is significantly higher
Geographic/regional/ market availability	Available within Australia

Table D2.2 Supplementary Indicators, Glass Fibre Reinforcement

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Information not available
Reusability/Adaptability/ Recyclability:	Not recyclable
Practical applicability:	This product can be used in a number of applications as an alternative to steel reinforcement. Specialist advice is required for structural applications. Currently the most beneficial use is in highly corrosive areas.

Polymer Injection Technology

Polymer Injection Technology is a patented process which partially substitutes the use of coke with polymers (like rubber) as an alternate carbon injectant to produce foaming slag Electric Arc Furnace (EAF) Steel.

A Professor from the University of New South Wales first developed the idea of using polymers as a partial Coke replacement in EAF facilities. This lead to a three year technological development and testing programme, in partnership with Onesteel, completed at the Sydney facility (World Steel Association 2010). The University of NSW holds the patents to this product and has granted Onesteel the exclusive right to sub-licence this technology for use around the globe (World Steel Association 2010).

This innovation offers an opportunity to improve steel cost efficiency while having a positive impact on the environment through energy savings and recycling polymers. Polymer injection of a rubber sourced from used vehicle tyres is now in commercial use at two EAF facilities in Sydney and Melbourne.

The following numbers provides a sample of results achieved at the Laverton Steel Mill during a recent trial under controlled conditions:

- Reduced specific electrical energy consumption
- Reduced carbon injectant of approximately 16%
- Increased furnace productivity (tonnes per minute) of 2%

(Onesteel 2009)

Reinforcing steel manufactured using polymer injection technology has been included in the Green Building Council of Australia's GreenStar Scheme.

The tables below illustrate the sustainability information for polymer injection technology.

Table D2.3 Core Indicators, Polymer Injection Technology

Indicator	Information
Embodied Carbon	Data has not yet been quantified for this material; however suppliers report a decrease in electricity use and heat requirements which would result in a reduction of embodied carbon.
Recycled content	Potential to recycle more than 285,000 used passenger tyres per year Recycled steel is used during the process (up to 60%)
Cost	Reduction in cost
Geographic/regional/ market availability	Available in Melbourne by Onesteel

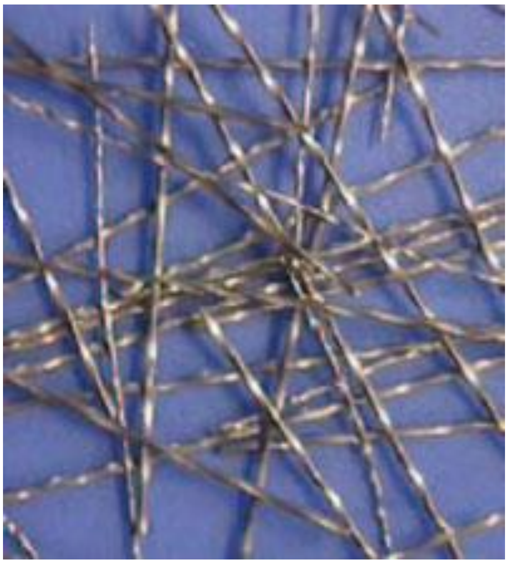
Table D2.4 Supplementary Indicators, Polymer Injection Technology

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Reduced NO_X SO_X and CO emissions
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	This product can be used for all applications where regular reinforcing steel is used

Twisted Steel Fibre Reinforcement

Twisted Steel Fibre Reinforcement, also known as Torex fibre, was originally designed by an American based company for the development of blast and earthquake resistant structures, Twisted Steel Fibre Reinforcement is a toothpick sized, coated (galvanised) metallic wire that has been twisted into a helix shape (**Figure D2.2**).

Figure D2.2 Twisted Steel Fibres



(*National Collegiate Inventors and Innovators Alliance, 2012*)

When millions of the small fibres are dispersed into concrete, they lock into place, forming a strong matrix that increases the concrete's blast and impact resistance up to five times over traditional concrete (National Collegiate Inventors and Innovators Alliance, 2012). The rectangular cross-sectional helix shape and twist increase the frictional resistance – each helix locking like a screw, rather than slipping out like a nail and the helix is to untwist before it fails. This results in a fundamental increase in performance to levels never before realised (Helix Steel 2012).

The density of the steel fibre within the concrete mix is dependent on the nature of the application. Twisted Steel Fibre Reinforcement can be used for the following applications:

- Structural walls
- Structural floors
- Foundations
- Piles/piers
- Pre-cast
- Beams/columns
- Shotcrete
- Tunnelling
- Paving

The benefits of using Twisted Steel Fibre Reinforcement rather than steel reinforcing bar or mesh for structural reinforcement include: reducing the amount of steel by weight within the concrete, reduced emissions because of reduced transport requirements, improved cost efficiency because of reduced labour time and improved work safety, increased first crack strength, increased crack resistance, increased durability and increased shear strength.

Table D2.5 Core Indicators, Twisted Steel Fibre Reinforcement

Indicator	Information
Embodied Carbon	There is no embodied energy data available for this product. There is an improvement associated with construction (70% reduction in steel usage, 400% reduction in heavy truck diesel fuel emissions because of shipping reductions). However, there is an increase in shipping/transport impact because the product is manufactured outside of Australia. Therefore, it is surmised that there would likely be only a slight improvement in embodied carbon
Recycled content	Made from 50% recycled steel (minimum, example from one supplier)
Cost	The product's manufacturer claims a 20% reduction in cost due to the elimination of labour associated with rebar-mesh placement along with reduction of waste steel
Geographic/regional/ market availability	This product is manufactured in the USA (Michigan). The product is shipped to storage facilities in each capital city of Australia where it is then shipped to construction sites

Table D2.6 Supplementary Indicators, Twisted Steel Fibre Reinforcement

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Reduced NO_X SO_X and CO pollutants through reduced onsite transport/construction emissions
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	This product can be used for all applications where regular reinforcing steel is used This product can be placed and finished using traditional concrete methods Performance of concrete is enhanced because it is galvanised steel (rust resistant), increased first crack strength, increased crack resistance, increased durability, increased shear strength

D2.2 Findings

The below tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D2.7 Core indicators, Concrete Reinforcement

Product	Carbon	Recycled content	Cost	Geographic /regional/market availability
Steel reinforcement	0	3	3	5
Glass fibre reinforcement	4	0	3	2
Polymer injection	2	4	4	4
Twisted Steel Fibre	1	8	4	0

Table D2.8 Supplementary indicators, Concrete Reinforcement

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Steel reinforcement	-	0	5	4
Glass fibre reinforcement	-	3	0	4
Polymer injection	-	4	5	5
Twisted Steel Fibre	-	3	5	5

The final weighted scores are shown below.

Table D2.9 Weighted scores, Concrete reinforcement

Material	Weighted Score (out of 100)
Reinforcing Steel	57.5
Polymer Injection	74.5
Glass-Fibre Reinforced	40.5
Twisted Steel Fibre	55

D2.3 Discussion

The second highest source of embodied carbon in concrete is the steel reinforcement, again providing an opportunity to reduce the embodied carbon in construction projects by considering alternative reinforcement materials and methodologies. The three alternatives discussed here, glass fibre-reinforced concrete, polymer injection technology, and twisted steel fibre reinforcement, represents sustainable alternatives for consideration.

Polymer injection technology is by far the most sustainable option, based on its locality, improved whole of life cost, and use of recycled steel. Twisted Steel Fibre Reinforcement has the potential to be a more sustainable alternative, but due to its manufacture outside of Australia, its rating has ended up lower than standard reinforcing steel.

D2.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D2.10 Manufacturers, Alternative Concrete Reinforcement

Polymer Injected Steel Reinforcement	Comments
Onesteel, EcoBar/EcoMesh	The use of polymer injection technology is currently operational in One-Steel's Sydney and Melbourne plants EcoBar and EcoMesh is available throughout Victoria and also uses up to 80% recycled steel in its production
Glass Fibre Reinforcement	**Comments**
V-Rod, GFRP bars and mesh	This supplier was a Canadian company that now manufactures and supplies in Australia.
Twisted Steel Fibre Reinforcement	**Comments**
Helix Steel, Twisted Steel Fibres	This supplier manufacturers this product within the USA at its single manufacturing facility. The product is then shipped to storage facilities in each Australian Capital City, and from there is transported to job sites. The product is available within Victoria.

All alternative products have a fairly weak market in Victoria. This is mainly because all alternatives are new and/or patented technologies.

Onesteel is the most accessible product and is the current supplier for some of the Councils within the IDM Group. This product is also manufactured within Victoria, which reduces its transport impact.

The Helix product is accessible within Victoria; however, it is not ideal because of the substantial transport impact associated with shipping it from the USA. The transport impact may also be amplified because the product is not shipped directly to the work-site, but is instead moved to the relevant State's where house and then moved to the job site.

Market improvements are limited for this product as it is produced by a single company. However, it is recommended that the IDM Group has discussions with the Helix representative to assess the potential for the following market improvements/influences:

- The use of local companies for transport from the Victorian storage area to the job site
- Employment of local businesses for distribution
- The implementation of a Community Plan/s that demonstrates Helix's contribution to the local community

D3 REINFORCED CONCRETE PIPE

D3.1 General

Reinforced concrete pipes generally use steel reinforcing for reinforcement.

Steel is an energy intensive material and its use (depending on the recycled content) can have a significant environmental impact. However, steel is one of the most recycled resources in the world, so it is most likely that steel reinforcement will be up to 60% recycled material.

Cellulose Fibre-reinforced concrete

Cellulose reinforced concrete pipes (CRCP) can be used as an alternative to the traditional steel reinforced concrete pipe. CRCPs are made from Ordinary Portland Cement, silica (ground sand particles), and cellulose fibre. The raw materials are mixed with water to form wet slurry in the mix plant.

The addition of the cellulose fibre to the concrete results in the following advantages:

- Typically manufactured in longer lengths which decrease the pipe laying time
- Improved durability due to the absence of potentially corrosive steel products
- The absence of steel means that the pipe can be more easily cut and reused
- Lightweight (approximately ½ the weight of steel reinforced pipe) composition means that transportation and installation is safer and more cost effective
- Exceeds the AS/NZ53726:2007 strength requirements

(HardiePipe Concrete Pipes 2010)

The tables below illustrate the sustainability information for Cellulose Fibre Reinforcement

Table D3.1.1 Core Indicators, Cellulose Fibre Reinforcement

Indicator	Information
Embodied Carbon	TBC
Recycled content	No recycled content
Cost	Whole of life costs are improved because of extended design life (no steel) and improved transportation and installation (30-40% faster installation) efficiencies
Geographic/regional/ market availability	Available in regional Victoria

Table D3.1.1 Supplementary Indicators, Cellulose Fibre Reinforcement

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Pollution reduction associated with steel extraction and processing
Reusability/Adaptability/ Recyclability:	100% recyclable for use as course aggregate
Practical applicability:	This product is suited to all applications that steel reinforced pipe is used. The lack of steel within the product means that it can be cut more easily and efficiently. The ability to reuse the off-cuts can also reduce overall waste.

D3.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D3..2.1 Core indicators, Reinforced Concrete Pipe

Product	Carbon	Recycled content	Cost	Geographic /regional/market availability
Steel reinforcement	-	3	3	5
Cellulose fibre reinforcement	-	3	4	4

Table D3.2.2 Supplementary indicators, Reinforced Concrete Pipe

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/ Adaptability/ Recyclability	Practical applicability
Steel reinforcement	-	0	5	4
Cellulose fibre reinforcement	-	1	5	5

The final weighted scores are shown below.

Table D3.2.3 Weighted scores, Reinforced Concrete Pipe

Material	Weighted Score (out of 100)
Steel reinforcement	57.5
Cellulose fibre reinforcement	61

D3.3 Discussion

As stated in Clause 9.5, the second highest source of embodied carbon in concrete is the steel reinforcement, meaning there is an opportunity to reduce the embodied carbon in construction projects by considering alternative reinforcement materials and methodologies. The alternative for use in concrete pipes discussed here, cellulose-reinforced concrete pipes, achieve reductions in pollution (associated with the extraction and processing of steel normally used as a reinforcement) and improved whole-of-life costs.

The improved whole-of-life costs are a result of improved durability and efficiencies in transportation and installation.

D3.4 Market assessment

One alternative was identified for reinforced concrete pipes. This product is Cellulose Fibre Reinforced Concrete Pipes

The only manufacturer identified is James Hardie, who produced the *HardiePipe,* which is a patented product.

Potentially, the local market be strengthened by encouraging James Hardie to use regional and local distributers and, where possible, staff.

D4 ASPHALT

D4.1 General

Asphalt concrete or hot mix asphalt (HMA) pavement, refers to the bound layers of a flexible pavement structure. For most applications, asphalt concrete is placed as HMA, which is a mixture of coarse and fine aggregate, and asphalt binder.

HMA is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 150°C for virgin asphalt and 166°C for polymer modified asphalt, and the asphalt cement at 95°C. Paving and compaction are carried out while the asphalt is sufficiently hot. HMAC is the form of asphalt concrete most commonly used on high traffic pavements such as those on major highways, racetracks and airfields.

Sustainability drivers

A significant number of steps are involved in the production and preparation of asphalt:

- Extraction of crude oil
- Transport to refinery
- Oil refining
- Quarrying of rock materials
- Preparation of aggregates
- Transport to markets

The result is that asphalt products generally have high embodied carbon, and a high use of non-recycled materials.

Paved areas also impact on the flow of surface water, minimising the infiltration of water and increasing the rate of overland flow and likelihood of flooding and stormwater pollution.

Research into current and emerging sustainable alternatives to the use of HMA focused on the following materials:

1 Warm mix asphalt
2 Resin bound porous pavement
3 Recycled aggregate asphalt
4 Recycled Plastic Addition
5 Crumbed Rubber Modified

Warm mix asphalt

Warm Mix Asphalt (WMA) is a technology that allows significant lowering of the production and paving temperature of conventional Hot Mix Asphalt (Zaumanis 2010).

WMA can be produced using two separate methodologies:

- Additive: The inclusion of the additive reduces mixing temperatures. This method can applied at any batch plant already preparing HMA
- Foam mix: Reduces the temperature of the mix, however requires modifications to batch plants

WMA offers significant benefits over conventional hot mix asphalt road surfacing methods (Australian Asphalt Pavement Association, n.d.). WMA is suitable for use as a direct replacement for HMA in a number of applications including

- Municipal roads
- Footpaths and pavements
- Parking and other hardstand areas
- Driveways

The tables below illustrate the sustainability information for WMA. Table D4.1 Core Indicators, WMA

Indicator	Information
Embodied Carbon	Lower embodied carbon (~30%) in production due to WMA being made at lower temperatures
Recycled content	Allows greater quantities of recycled asphalt to be used in the mix
Cost	Application cost is higher than HMA by approximately 20%
Geographic/regional/ market availability	Available in regional Victoria Can be transported longer distances than HMA

Table D4.2 Supplementary Indicators, WMA

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Water usage performance</td><td>N/A (supplier dependent)</td></tr>
<tr><td>Pollutants (other than greenhouse gas):</td><td>Reduced fumes in production of WMA
55% reduction in fine dust
58% reduction of NO_x
80% reduction in SO_x</td></tr>
<tr><td>Supply Chain/Processing</td><td>N/A (supplier dependent)</td></tr>
<tr><td>Reusability/Adaptability/ Recyclability:</td><td>Both WMA and HMA are 100% recyclable</td></tr>
<tr><td>Practical applicability:</td><td>WMA is produced at a much lower temperature which results in more comfortable and safer workplaces
Improved productivity through an extended paving season and longer haul distances as WMA is easier to compact at lower temperatures.
WMA can generally be used in all applications HMA is commonly used:
WMA allows roads to be opened to traffic sooner due to lower compaction temperatures
<table>
<tr><th>Common use for HMA</th><th>WMA suitable</th><th>Examples</th></tr>
<tr><td>General road paving</td><td>Yes</td><td>VicRoads approved</td></tr>
<tr><td>High traffic road paving</td><td>Yes</td><td>VicRoads approved</td></tr>
<tr><td>Parking areas and hardstand</td><td>Yes</td><td>VicRoads approved</td></tr>
<tr><td>Footpaths</td><td>Yes</td><td>Successfully applied by a Queensland local Council</td></tr>
</table>
</td></tr>
</table>

Resin bound porous pavement

Resin Bound Porous Pavements (RBPP) provide a water saving and pollution-minimising alternative to traditional asphalt pavements. RBPP can use stone, glass or mixed aggregate as a feedstock, however, this assessment focuses on the use of stone within the mix.

RBPPs can generally be used for pedestrian and low-medium traffic areas, including tree surrounds. By weight (according to one manufacturer), RBPP consists of 95% natural stone, recycled stone or recycled glass and 5% resin.

RBPPs allow water to seep through the resin bound aggregate into a free draining structural pavement layer (that also traps contaminants and pollutants) and then either into the stormwater system, a detention system or to the natural soil beneath. Each stone is coated in resin, allowing points of contact to fuse securely whilst leaving voids through which water can flow, enabling drainage.

Porous pavement achieves benefits in the following areas (Shackel, 2010):

- Reduces rainfall runoff from pavement surfaces
- Reduces the size or need for rainwater retention facilities in roadworks by using the pavement itself for retention. This reduces land use
- Reduces downstream flooding
- Recharges and maintains aquifers and the natural groundwater
- Traps pollutants that would otherwise contaminate groundwater or drainage systems
- Assist in the biological decomposition of hydrocarbon contaminants. Permeable pavements may require frequent maintenance because grit or gravel can block the open pores. This is commonly completed by industrial vacuums that suck up the deposited sediment. With more advanced paving systems the levels of maintenance required can be greatly decreased
- The tables below illustrate the sustainability information for RBPP.

Table D4.3 Core Indicators, Resin Bound Porous Pavement

Indicator	Information
Embodied Carbon	Whilst specific data is not currently available, one study concludes that approximately 50% saving in embodied carbon when a permeable pavement is used instead of a conventionally drained pavement
Recycled content	Can make use of recycled stone/aggregate/glass from on-site or off
Cost	Increase in initial cost but the whole of life is better
Geographic/regional/ market availability	This is a widely available product

Table D4.4 Supplementary Indicators, Resin Bound Porous Pavement

Indicator	Information
Water usage performance	The water performance is dependent on the system selected. For example, a superior system would function as a closed loop and use the water captured in the detention

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td></td><td>system on or around the site. A lesser system filters and captures pollutants and discharges the water to the stormwater system
Regardless of the system, porous pavement assists with flood control and run-off control</td></tr>
<tr><td>Pollutants (other than greenhouse gas):</td><td>Reduction in the amount of pollutants entering the water system</td></tr>
<tr><td>Reusability/Adaptability/ Recyclability:</td><td>This material could potentially be recycled for use as Recycled aggregate</td></tr>
<tr><td>Practical applicability:</td><td>RBPP can be used with limited applications.
This product has a life-span of approximately 20 years if properly maintained (cleaned to avoid clogging)
<table>
<tr><th>Common use for HMA</th><th>RBPP suitable?</th><th>Examples</th></tr>
<tr><td>General road paving</td><td>No</td><td>n/a</td></tr>
<tr><td>High traffic road paving</td><td>No</td><td>n/a</td></tr>
<tr><td>Parking areas and hardstand</td><td>Yes</td><td></td></tr>
<tr><td>Footpaths</td><td>Yes</td><td></td></tr>
</table></td></tr>
</table>

Recycled Aggregate Asphalt

Recycled or Reclaimed Asphalt Pavement (RAP) consists of excavated asphalt pavement which is crushed and screened to suit different grading requirements. Asphalt containing RAP is produced by combining the recycled aggregate and binder with virgin aggregate and a new binder.

It is currently acceptable in most states of Australia to include a prescribed proportion of RAP within asphalt mix (generally between 10-30%). The amount of RAP used within a mix is relative to the type of binder required, for example, for up to 15% RAP by weight of total mix (low RAP), no change in binder grade is required, but for 16-25% RAP, by weight of total mix (intermediate RAP content) a lower binder grade (softer binder) is required.

The level of RAP used in HMA is restricted to 50% due to maximum heat capacity and emissions. Warm Mix Asphalt, which is processed at a much lower temperature, could potentially use much higher amounts of RAP.

The benefits of using RAP include (Soward and Vos, 2009):

- Reduced energy consumption
- Conserving raw materials
- Reduced cost

The tables below illustrate the sustainability information for RAP.

Table D4.5 Core Indicators, RAP

Indicator	Information
Embodied Carbon	Embodied energy in RAP is approximately 46% lower than in equivalent quarry products
Recycled content	100% recycled product Requires some reprocessing The binder on the RAP is reactivated by the heat from the virgin aggregate during mixing, therefore the amount of bitumen binder can be reduced.
Cost	Assuming that the RAP is sourced locally there is a reduction in cost
Geographic/regional/ market availability	Commonly available Where possible, on-site RAP should be used before sourcing externally

Table D4.6 Supplementary Indicators, RAP

Indicator	Information
Water usage performance	Significant amount of water from the extraction of virgin material is saved There was no information available regarding the reprocessing
Pollutants (other than greenhouse gas):	Reduction in pollutants caused through extraction
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	RAP can generally be used in all applications HMA is commonly used. RAP mixes age more slowly and are more resistant to the action of water than conventional mixes **Common use for HMA** — **RAP suitable** General road paving — Yes High traffic road paving — Yes Parking areas and hardstand — Yes Footpaths — Yes

Recyled Plastic Addition, (RPA)

There have recently been a spate of local government pavement trials around the country including Craigeburn Vic, Snug Tas, Engadine Sydney NSW, Happy Valley SA and Canberra ACT involving a new asphalt admixture developed from plastic bags, printer cartridges toner material, crushed glass and recycled asphalt product (RAP). The admixture has been developed by recycling company Close the Loop and Downer Group. The plastic bags and printer cartridges are refined and added to the asphalt mix as a substitute for virgin hydrocarbons. Recycled glass is crushed to form a sand product and added to the admixture along with RAP. Purported benefits are harder wearing longer pavement life and improved deformation resistance compared to traditional asphalt admixtures, and asphalt admixtures containing over 25% total recycled material content. Plastic addition can also reduce the viscosity of the mix, hence lowering working temperatures.

Quoted figures per km of two lane road include the use of 530,000 plastic bags, 170,000 glass bottles, toner from 12, 500 cartridges per km. Plastics are not restricted to plastic bags but can include other soft plastics including PET, PVC, PP, HDPE and LDPE hence an Australian wide ban on plastic bags would not necessarily prevent plastic being utilised as an additive. Also, different plastic types can be used in the same mix so reducing the requirements for segrating plastic waste.

While RPA is new in Australia, it is worth noting that India in particular has been utilising plastic waste as a asphalt additive for a number of years, with sources suggesting over 33,000 km of roads have either been constructed or resurfaced using recycled plastic additives, with the technology being developed over 15 years ago.

The tables below illustrate the sustainability information for Recycled Plastic Addition. RAP and recycled glass is considered in other sections.

Table D4.7 Core Indicators, Recycled Plastic Addition

Indicator	Information
Embodied Carbon	Very low. As recycled material is used then the primary addition is the carbon emitted during reprocessing
Recycled content	Downer have indicated up to 30% recycled content, although the proportion of soft plastics and toner is not specified
Cost	Not disclosed
Geographic/regional/ market availability	Plant in Lake Macquarie. Unknown at this stage whether plants can locally produce in Victoria

Table D4.8 Supplementary Indicators, Recycled Plastic Addition

Indicator	Information
Water usage performance	N/A
Pollutants (other than greenhouse gas):	N/A
Reusability/Adaptability/ Recyclability:	Road surfaces utilising the RPA additives can be recycled.
Practical applicability:	As these are trial developments, Vic Roads Technical Note TN 107 Use of Recycled Materials for Road Construction has not yet been updated to reflect the addition of plastics to the admixtures. A number of trials have been implemented across the country as has been previously indicated

Recycled Tyres

Areas of research have focused on the following;

CRM – Crumb Rubber Modified
Retaining wall system

CRM – Crumb Rubber Modified

Crumed Rubber Modified involves the shredding of waste tyres and extraction natural rubbers and carbon black. As advised by SAMI Bitumen in a recent roads and infrastructure article, the former reduces the need for polymer binders and the latter is an anti oxidant which retards the ageing of the binder.

Recent Developments

While CRM has been used in spray seal binders since the 1970's it is not widely used in asphalt applications within Australia. Recent work however has seen in the utilisation of CRM in Open Graded Asphalt (OGA) and Gap Graded Asphalt (GGA) with the development by the Australian Asphalt Pavement Association (AAPA), Tyre Stewardship Australia (TSA) and others of a pilot specification released in June 2018. AAPA reports that the OGA mix design process has been validated through demonstration trials in Australia but the GGA mix yet to be validated through demonstration trials in Australia. The aim of specification is to foster the development of demonstration trials of CRM GGA mixes and promote the use of CRM in OGA within Australia. Roads and Maritime Services (RMS) NSW have very recently (May 2019) introduced a specification for CRM including a warm mix option.

Renewal of TSA levy scheme

TSA has recently (mid 2018) had its scheme of placing a 25 cent levy on tyres sold for research and development of uses for waste tyres reauthorised for another six years by the Australian Competition and Consumer Commission (ACCC). As part of this scheme, TSA has introduced a Demonstration and Infrastructure section to its Market Development fund. This section will go towards dollar for dollar grants for infrastructure and demonstration projects that generate consumption of waste tyres on an ongoing basis.

Dense graded asphalt trial

A recent trial of CRM has been initiated by the City of Mitcham in Adelaide. The trial comprises of a 355 metre long section of road incorporating a dense grade asphalt warm mix CRM mix. The number of waste tyres consumed was 850, averaging 1.5 tyres per every tonne of asphalt. Purported benefits (to be verified by the trial) are improved pavement durability, resulting in longer life. The trial has been conducted on a section of road constructed over expansive clay geology which has resulted in premature failure of the existing conventional pavement.

Retaining Wall System

Tyres used in wall system

As reported in roads online a high performance wall system has been recently developed by TSA accredited recycler Lornwest Enterprises based in Perth, Western Australia. The wall system comprises of tightly baled waste tyres contained within concrete skins. The walls can be utilised for a number of applications including retaining walls and sound barriers. Operational testing is underway of the walls as sound barriers has commenced within several municipalities in Western Australia. The wall system is modular which allows structures of any length or practical height to be achieved. Refer to **Figure D4.1.**

At the end of the walls life the tyres can either be reused or shredded for CRM and the concrete faces stripped off by an excavator and crushed for use in road base.

Figure D4.1 Retaining wall system

Lornwest

The tables below illustrate the sustainability information for CRM in Asphalt.

Table D4.9 Core Indicators, CRM

Indicator	Information
Embodied Carbon	Very low. As recycled material is used then the primary addition is the carbon emitted during crumbing
Recycled content	2.0% (RMS draft specification May 2019[3]) to 4%
Cost	Not disclosed
Geographic/regional/ market availability	

Table D4.10 Supplementary Indicators, CRM

Indicator	Information
Water usage performance	N/A
Pollutants (other than greenhouse gas):	N/A
Reusability/Adaptability/ Recyclability:	Road surfaces using crumb rubber can be recycled.
Practical applicability:	Possibly not yet widely applicable in Australia – widely used overseas but more trial results for Australia may be required. Noted that RMS have just introduced a specification (May 2019) for high bearing surface with CRM also available as warm mix.

[3] Roads and Maritime Services (RMS) QA Specification R118 Crumb Rubber Asphalt May 2019. https://www.rms.nsw.gov.au/business-industry/partners-suppliers/documents/specifications/r118.pdf

D4.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D4.11 Core indicators, Asphalt

Product	Carbon	Recycled content	Cost	Geographic /regional/market availability
HMA	0	0	5	5
WMA	3	2	5	5
RBPP	4	2	4	4
RAP	4	3	4	4
RPA	1	1	4	1
RPA including crushed glass	3	2	4	1
CRM	1	1	4	2

RPA and CRM scores currently are limited by availability across regional areas. We expect the scores to improve over the next few years and, where the product is already available the score becomes 60 or more. The following notes specifically refer to RPA and CRM;

Note 1 - Asphalt admixture is high in embodied carbon. Given the current low proportion of plastic and CRM that can currently be included in the mix - only a few percent, RPA and CRM will not currently result in significant reductions in embodied carbon.

Note 2 - the environmental benefits of RPA are potentially huge as it can divert plastic bags and plastic bottles from landfill. This is not highlighted in the score. Similar comments apply to CRM.

Note 3 - While CRM and RPA are currently more expensive than say HMA, they have the potential to extend the life of the pavement, hence the high score on cost.

Note 4 - RPA has been included in isolation. However the current trials that have been carried out by Downer include crushed glass within the mix which improves the ratings.

Table D4.12 Supplementary indicators, Asphalt

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/ Adaptability/ Recyclability	Practical applicability
HMA	0	0	5	4
WMA	2	3	5	5
RBPP	4	4	4	3
RAP	3	3	5	4
RPA	4	4	5	4

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/ Adaptability/ Recyclability	Practical applicability
RPA including crushed glass	4	3	5	4
CRM	4	4	5	4

The final weighted scores are shown below.

Table D4.13 Weighted scores, Asphalt

Material	Weighted Score (out of 100)
HMA	50
WMA	76
Resin bound Pavement	69.5
RAP	74.5
RPA	45
RPA including crushed glass	55.5
CRM	49

RPA and CRM scores currently are limited by availability across regional areas. We expect the scores to improve over the next few years and, where the product is already available the score becomes 60, 71.5 and 61 in order. There are notes above specifically refering to RPA and CRM;

D4.3 Discussion

With high embodied carbon, and no recycled content, opportunities exist for improving construction project sustainability through consideration of hot mix asphalt alternatives.

The three alternatives discussed here; warm mix asphalt, resin-bound porous pavement, and recycled aggregate asphalt, are all currently available in regional Victoria and can be substituted for hot mix asphalt for most applications.

D4.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D4.14 Manufacturers, Alternative Asphalt

Warm Mix Asphalt (WMA)	**Comments**
Citywide, *Greenpave*	This is a Melbourne based company, and is currently used with VicRoads projects
Boral, *Warm Pave*	Readily available and mixed within Victoria Boral's brand of 'Green asphalt' uses reclaimed asphalt and warm mix technologies
Alex Fraser Asphalt	This company services the Melbourne region
Fulton Hogan	Available across Victoria
Resin Bound Pavement[1]	**Comments**
StoneSet, Porous Water Sensitive Paving	NSW based company but a plant and registered suppliers are present within Melbourne and regional Victoria, respectively The sales manager stated that where possible recyclable stones and glass are sourced as close to the site as possible with the resin (5% of mix) being imported from NSW There is potential that on-site waste could be used in the mix
MPS Paving, permeable paving	Berwick, Victoria
Dymon, Porous Pave	This product is mainly applicable to tree surrounds and garden beds Decorative finish
Porous Paving Solutions	Available in NSW and SA
Recycled Plastic Addtion	Comments
Downer, *Toner Pave and Toner Seal*	Downer indicated these products have been in use for about five years, but only contained around 1% of recycled resources
Downer, *Plastiphalt*	Has been used on a trial basis at various locations around the country
Downer, *Reconophalt*	Downer have recently overhauled their plant at Teralba, Lake Macquarie to produce a wide range of asphalt products utilising recycled materials including production of Reconphalt. This product supercedes Plastipahlt.
Recycled Aggregate Asphalt (product)[1]	**Comments**
Boral, low carbon asphalt	Readily available and mixed within Victoria Boral's brand of 'Green asphalt' uses reclaimed asphalt and warm mix technologies
Alex Fraser Asphalt	This brand of Asphalt contains up to 40% recycled material The company currently services the Melbourne region

1. Recycled aggregates (and/or glass waste) can be purchased from landfills and waste processing centres and supplied to local asphalt manufactures or resin bound pavement manufactures for inclusion in the mix. This material is readily available throughout Victoria

Warm Mix Asphalt

WMA and the use of recycled aggregates in both HMA and WMA is becoming common practice, especially in Victoria given the uptake of the technologies by VicRoads.

t is noted that a supplier of HMA can make WMA through including a wax additive in their mix. This additive allows the asphalt to be mixed at a lower temperature. Currently, there is a strong supply of WMA within regional and metropolitan Victoria but the market is being led by major industry players. Smaller companies can be encouraged to make WMA through demand and education on the manufacturing process.

Resin Bound Porous Pavement

The market for resin bound pavements is also relatively strong with many major and specialty companies producing the sustainable alternative.

Recycled Plastic Addition

The refurbishment of the Downer Teralba plant at Lake Macquarie to allow RPA would appear to be at least in part due to a recent Lake Macquarie City Council initiative to develop end markets for paper and plastics within the Hunter region.

Also, due to the National Swrod Policy implemented in China which has cut off many waste plastic imports and is resulting in the increased stockpiling of waste plastics within Australia, it is expected that the market for RPA will increase in coming years. To facilitate this however there will need to be significant upscaling of the additive manufacturing sector, evaluation of the road trials currently in place, acceptance by councils and road authorities, and development of regulatory standards.

D5 AGGREGATES (NATURAL GRAVELS AND SANDS)

D5.1 General

Both coarse aggregates (stone fractions) and fine aggregates (sand fractions) are quarried and/or dredged for use in concrete, asphalt, road base, and civil works (including bedding and backfill applications for trenches and retaining walls).

Aggregates are obtained by a variety of means, including ripping, blasting and dredging. The raw materials are processed by crushing, screening, washing, blending and grading. (*Sustainable Concrete Materials*, Cement Concrete and Aggregates Australia).

Construction aggregates produced from natural sources such as gravel and sand.

Sustainability drivers

In general the quarrying activities associated with obtaining virgin aggregate materials are energy intensive (e.g. ripping and blasting). Further, the transport distances from quarry sites to project sites can often be significant. Virgin aggregate materials will therefore generally have relatively high embodied carbon.

Additional drivers, other than carbon, for identifying alternative aggregates include: reducing natural resource consumption, diversion of waste from landfill, reduced quarrying which conserves ecosystems and biodiversity, and increasing quarry transport distances particular in metropolitan areas due to diminishing quarry resources.

Research into current sustainable alternatives to the use of virgin aggregates and natural gravels and sands focused on the following materials:

- Manufactured sand
- Crushed glass
- Crushed concrete (ground as sand)

Manufactured sand

Manufactured sand is a purpose-made crushed fine aggregate produced from a suitable source material and designed for use in concrete or road construction. Manufactured sand is made by reprocessing waste material generated through the production of course aggregates at quarries. The waste material is generally finer than 5mm, and with variable properties. Production of manufactured sand from this waste material generally involves crushing, screening and possibly washing (Use of Recycled Aggregates in Construction. *Cement Concrete & Aggregates Australia*).

Manufactured sand is defined as a purpose made crushed fine aggregate produced from a suitable source material, and is meant to replace a proportion of natural sand within the mix.

Research by the concrete and extractive industries has shown that, provided the material is appropriately processed and selected from suitable materials, a significant proportion of naturally-extracted sand can be replaced by manufactured sand, while still meeting high-quality concrete specifications.

The tables below illustrate the sustainability information for Manufactured Sand.

Table D5.1 Core Indicators, Manufactured Sand

Indicator	Information
Embodied Carbon	Actual data is not currently available, however embodied energy is reduced as the manufactured sand is a waste product from aggregate quarrying.
Recycled content	100% recycled content
Cost	A cost benefit exists where travel distances are comparable with those for virgin materials
Geographic/regional/ market availability	Reasonably available product, available in regional Victoria.

Table D5.2 Supplementary Indicators, Manufactured Sand

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	No difference to natural sand
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Manufactured sand can be used for a proportion of the sand mix for all applications

Crushed glass cullet (sand)

Crushed glass cullet (glass sand) is the waste material or *glass fines* that are produced during the glass recycling process. These fines are not suitable for reuse in recycled glass containers or bottles but can be used as a sand replacement within the construction industry. To prepare the fines for use they are screened, vacuumed, crushed and graded to produce washed glass sand.

Once pulverised into a sand-like product and combined as a proportion of a natural sand mix, there are a number of applications for this product. For example, non-structural concrete aggregate, bedding and backfill material, pavement base and sub-base, asphalt, fill material and, drainage.

A 2003 scoping study by the Australian Environment Business Network found that approximately 15,000 tonnes of glass fines currently going to landfill annually in New South Wales could be used in asphalt. (Cement Concrete & Aggregates Australia).

Whilst there has been some controversy surrounding glass cullet reuse due to concerns over it potentially containing crystalline silica, (a cause of silicosis and a known carcinogen), it is worth noting that tests completed by Sydney Water (Department of Environment and Climate Change NSW 2007) show that the dust generated by glass cullet is not considered hazardous and does not contribute to silicosis or cancer.

Recent Developments

As indicated in the section on recycled plastic addition, asphalt additive mixes are being developed to include sand derived from crushed glass.

Glass fines are currently listed in Technical Note TN 107 (last updated in September 2011) as being permitted for use as a replacement for natural sands in Asphalt Admixtures. The proportion of glass fines within the asphalt admixture is not specified within this note hence the mix design must be registered in accordance with VicRoads Code of Practice.The proportion of glass fines within the proposed mix is dependant on approval by VicRoads. Based on discussions with Alex Fraser Group), VicRoads have typically permitted up to 5% of glass fines within asphalt admixtures over the last ten years but there does not appear to have been any recent wide spread increase to this proportion.The tables below illustrate the sustainability information for crushed glass cullet (glass sand).

Table D5.3 Core Indicators, Glass Cullet

Indicator	Information
Embodied Carbon	Reduced embodied energy as the cullet is a 'waste' product from glass recycling processes
Recycled content	100% recycled content This produce is a waste material that would otherwise be sent to landfill
Cost	The cost for the recycled product (from recyclers) is cheaper than for natural sand assuming that the transportation distance is not significant
Geographic/regional/ market availability	Glass cullet is a widely available product, it is sold through recycling facilities, concrete manufacturers and some specialist providers

Table D5.4 Supplementary Indicators, Glass Cullet

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Water usage performance</td><td>N/A (supplier dependent)</td></tr>
<tr><td>Pollutants (other than greenhouse gas):</td><td>No difference with natural sand, the risk of pollution could potentially be higher due to residual contaminants</td></tr>
<tr><td>Reusability/Adaptability/ Recyclability:</td><td>100% recyclable</td></tr>
<tr><td>Practical applicability:</td><td>Crushed Glass Cullet can be used within most applications, as shown in the table below.
As natural sands become more scarce and the transport distances to certain parts of the country increase, the cost efficiency of recycled glass cullet will be significantly improved
<table>
<tr><th>Common use for Natural sands</th><th>Glass Cullet suitable</th><th>Examples</th></tr>
<tr><td>Concrete aggregate</td><td>Yes</td><td>Local example could not be identified</td></tr>
<tr><td>Cement mix</td><td>Yes</td><td>Trials completed in NSW by DECC which shows partial replacement is suitable</td></tr>
<tr><td>Pavement Sub-base/Base</td><td>Yes</td><td></td></tr>
<tr><td>Asphalt</td><td>Yes</td><td>Recently used on CityLink Tullamarine freeway widending project by Fulton Hogan</td></tr>
<tr><td>Backfill and bedding</td><td>Yes</td><td>VicRoads approved, DECC NSW approved</td></tr>
<tr><td>Paving applications</td><td>Yes</td><td>Successful trials completed in Waverly by Waverly Council, NSW</td></tr>
</table>
</td></tr>
</table>

Crushed concrete (Sand) – Recycled Concrete Aggregate
Recycled Concrete Aggregate is produced by crushing clean (low contamination level) demolition waste of at "least 95% by weight of concrete" (Cement Concrete and Aggregates Australia 2008). Waste material like steel and other contaminants are removed during crushing (generally with magnets). Other materials that may be present in RCA are gravel, sand, and crushed stone. In Australia, RCA is one of the most common construction and demolition wastes used in concrete production both as coarse and fine aggregate (Cement Concrete and Aggregates Australia 2008).

Table D5.5 Core Indicators, Crushed Concrete (sand)

Indicator	Information
Embodied Carbon	30% reduction in processing compared with virgin material (based on assumption that transport would be no more than 5km more than the virgin material)
Recycled content	100% recycled content
Cost	On-site waste can be used Can purchase from supplier but the transportation distances should be kept low to maintain profitability
Geographic/regional/ market availability	Available in regional Victoria Very common product

Table D5.6 Supplementary Indicators, Crushed Concrete (sand)

Indicator	Information
Water usage performance	The water performance during mixing is lower as the absorption rate is higher than with virgin aggregates
Pollutants (other than greenhouse gas):	Generally, similar to virgin material, no additional chemicals are required to process
Reusability/Adaptability/Recyclability:	100% recyclable
Practical applicability:	RCA is applicable for most aggregate application Not more than 30-40% inclusion of this aggregate substitute product is recommended in a concrete mix If the crushed concrete is highly contaminated with brick (etc.) it should be used for backfill, cleaner products can be used for pavement and concrete mixes

D5.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D5.7 Core indicators, Aggregates (natural gravels and sands)

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Aggregates (natural gravels and sands)	0	0	4	5
Manufactured sand	3	4	4	5
Crushed glass cullet (sand)	3	4	5	4
Crushed concrete (sand)	4	5	5	5

Table D5.8 Supplementary indicators, Aggregates (natural gravels and sands)

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/ Adaptability/ Recyclability	Practical applicability
Aggregates (natural gravels and sands)	0	0	5	4
Manufactured sand	2	1	5	4
Crushed glass cullet (sand)	2	1	5	4
Crushed concrete (sand)	4	4	5	4

The final weighted scores are shown below.

Table D5.9 Weighted scores, Aggregates (natural gravels and sands)

Material	Weighted Score (out of 100)
Natural gravel and sands	49
Manufactured sand	79.5
Crushed glass	80.5
Crushed Concrete	95

D5.3 Discussion

With a requirement for highly energy intensive activities to quarry virgin aggregate materials, there exists an opportunity to improve construction project sustainability through consideration of the use of recycled materials.

The three alternatives discussed here, manufactured sand, crushed glass cullet, and crushed concrete (sand), are all generally available in regional Victoria and can be substituted for virgin materials for all applications.

As the alternatives are recycled waste products, they represent a substantial improvement in terms of both reduction of embodied carbon, use of recycled content and reduced potential for pollution.

D5.4 Market assessment

The following list of alternative aggregates has been addressed throughout this study:

- Crushed concrete (as sand and rock)
- Reclaimed aggregate
- Manufactured Sand
- Crushed Glass Cullet

The market for the above materials is very well established within Victoria and the rest of Australia. Most concrete manufacturers and supplier will supply manufactured sand, and a blend which includes crushed glass. Reclaimed aggregate and crushed concrete is available from most major asphalt and concrete suppliers.

Finally, much of the construction waste collected on-site during works can be reprocessed and reused within pavements, backfill and/or concrete surfacing. Many concrete and pavement suppliers will allow this arrangement.

It is anticipated that the demand and cost efficiency for sand alternatives within regional parts of Australia will improve as stocks of natural sands diminish and the market is forced to source sand closer to coastal areas.

D6 AGGREGATES (CRUSHED ROCK)

D6.1 General

Both coarse aggregates (stone fractions) and fine aggregates (sand fractions) are quarried and/or dredged for use in concrete, asphalt, road base, and civil works (including bedding and backfill applications for trenches and retaining walls).

Aggregates are obtained by a variety of means, including ripping, blasting and dredging. The raw materials are processed by crushing, screening, washing, blending and grading (Cement Concrete and Aggregates Australia).

Crushed rock is a form of construction aggregate, typically produced by mining a suitable rock deposit and breaking the removed rock down to the desired size using crushers. It is distinct from gravel which is produced by natural processes of weathering and erosion, and typically has a more rounded shape.

Sustainability drivers

In general the quarrying activities associated with obtaining virgin aggregate materials are energy intensive (e.g. ripping and blasting). Further, the transport distances from quarry sites to project sites can often be significant. Virgin aggregate materials will therefore generally have relatively high embodied carbon.

Research into current and emerging sustainable alternatives to the use of virgin aggregates and natural gravels and sands focused on the following materials:

- Crushed concrete
- Recycled glass
- Recycled gravel/reclaimed aggregates

Crushed concrete

See **Clause 9.4** – note data used in analysis of crushed concrete was not sufficiently granular to differentiate between crushed concrete used as a rock replacement or as a sand replacement (for indicators such as embodied carbon for example).

Recycled gravel/reclaimed aggregates

In many countries, including Australia, recycled gravel (reclaimed concrete or pavement aggregates) has been proven to be practical for most concrete applications, including low-strength and structural-grade concretes. They can also be used as a component of bedding or backfill. The level of acceptance within the engineering community for using this product is still moderate, however, a number of Councils and State Departments (particularly in Victoria) now specify up-to 40% inclusion of recycled and reclaimed aggregates within concrete mix and bedding.

The aggregates can be reclaimed from the concrete using a number of technologies, with a requirement to wash the aggregates where a clean single size aggregate is required. The water may or may not be reclaimed, and the aggregates are screened for later use, either stockpiled on site, or transported to the new project site.

Positive benefits include:

- The amount of material going to land fill is reduced
- Aggregates from selected materials and industrial by-products may be used economically in concrete and as road construction materials

(Cement Concrete and Aggregates Australia)

The tables below illustrate the sustainability information for recycled aggregate.

Table D6.1 Core Indicators, Recycled Aggregate

Indicator	Information
Embodied Carbon	Embodied carbon in recycled gravels is considerably lower than virgin aggregates however actual data has not been found.
Recycled content	100% recycled content
Cost	On-site waste can be used Can purchase from supplier but the transportation distances should be kept low to maintain profitability
Geographic/regional/ market availability	Available in regional Victoria Very common product

Table D6.2 Supplementary Indicators, Recycled Aggregate

Indicator	Information
Water usage performance	0.88 KL/t of water is saved by avoiding extraction
Pollutants (other than greenhouse gas):	Information not available
Reusability/Adaptability/Recyclability:	100% recyclable
Practical applicability:	Recycled aggregate maintains its properties throughout the reclamation process and can therefore be used for the same applications as the virgin material

Recycled glass (rock replacement)

Crushed Glass can potentially be used within pavements and concrete as an alternative to gravel and natural aggregates.

The use of this material gives a number of benefits:

- Reuse of mixed coloured glass that cannot be recycled into new glass bottles and containers
- Conservation of natural resources
- Reduced carbon impact
- Maintained long-term performance of asphalt or concrete.

The use of glass as a rock replacement in asphalt is sometimes called 'Glassphalt' and can be installed using the same equipment and procedures as conventional asphalt (Clean Washington Centre n.d.).

To make sure the glass surfacing is of no danger to cars and/or people, a large amount of re-processing is required. To help to overcome this risk a shaping crushing plant can be used in the crushing circuit (Fulton, 2008).

The grading of the glass should be dictated by the required use. For example, roads intended for car travel faster than approximately 60km/hr should use glass no larger than half an inch (5% lower than that of conventional asphalt). Glass intended for a sub-base can have a higher grading because skid resistance stripping is not an issue (Clean Washington Centre n.d.).

Once the grading is performed the glass is mixed with the natural (virgin or recycled) aggregate to get a uniform glass/rock mix prior to mixing with the other asphalt components. An anti-stripping agent should be used in the asphalt mix to reduce the risk of early failure (Clean Washington Centre n.d.).

Recent developments

In Victoria crushed glass is permitted for use with Class 2, 3 and 4 base course material, with the final proportion dependant on approval by VicRoads as part of the mix design registration. Alex Fraser Group have indicated that the VicRoads have recently, (within the last couple of years) registered mix designs with up to 15% crushed glass for class 2, 3 and 4 material which represents an increase over previous years.he tables below illustrate the sustainability information for recycled glass as rock replacement.

Table D6.3 Core Indicators, Recycled Glass (rock replacement)

Indicator	Information
Embodied Carbon	Embodied carbon in recycled glass is approximately 30% less than using virgin materials
Recycled content	100% recycled
Cost	Reduction in cost, especially if Council are using the materials collected through their municipal waste collection system Long whole of life cost
Geographic/regional/ market availability	This product would be readily available from any recycling centre

Table D6.4 Supplementary Indicators, Recycled Glass (rock replacement)

Indicator	Information
Water usage performance	N/A information not available
Pollutants (other than greenhouse gas):	Reduction in pollution compared with natural aggregates because extraction is not required The pollution is still relatively high because of the high amount of reprocessing required
Reusability/Adaptability/ Recyclability:	Recyclable within the asphalt or concrete mix
Practical applicability:	The use of recycled glass in aggregates is not widely accepted within Australia, however, in the USA and UK it has been used for the last couple of decades. Recycled glass can be used in the following applications: low-medium traffic roads, concrete, asphalt (pedestrian), parking areas etc.

D6.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D6.5 Core indicators, Aggregate (crushed rock)

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Aggregates (crushed rock)	0	0	4	4
Crushed concrete	4	5	5	5
Recycled/reclaimed aggregates	3	5	5	5
Recycled Glass	3	4	5	3

Table D6.6 Supplementary indicators, Aggregate (crushed rock)

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Aggregates (crushed rock)	0	0	5	4
Crushed concrete	4	4	5	4
Recycled/reclaimed aggregates	2	3	5	4
Recycled Glass	2	1	5	3

The final weighted scores are shown below.

Table D6.7 Weighted scores, Aggregate (crushed rock)

Material	Weighted Score (out of 100)
Crushed rock, virgin	45
Crushed concrete	95
Recycled gravel	90.5
Recycled glass	75.5

D6.3 Discussion

With a requirement for highly energy intensive activities to quarry virgin aggregate materials, there exists an opportunity to improve construction project sustainability through consideration of the use of recycled materials.

The three alternatives discussed here, crushed concrete, recycled/reclaimed aggregates and recycled glass, are generally available in regional Victoria and can often be substituted for virgin materials for some applications.

As the alternatives are recycled waste products, they represent a substantial improvement in terms of both reduction of embodied carbon, use of recycled content and reduced potential for pollution.

D6.4 Market assessment

Alex Fraser Group have indicated that within Victoria, recycled glass has been used over the last ten years for both asphalt sand additives, and base course additives. A current example is the recently completed Citylink Tullamarine Freeway widening project which is understood to have utilised over 40 million glass bottles, (nominally around 9000 tonnes based on full utilisation of the bottle). Recycled glass has been utilised for both base course aggregates and asphalt mixes

It is expected that the increasing publicity attributed to use of recycled crushed glass as a road material is in part due to growing public awareness of green projects rather than an increase in usage of recycled glass as a road construction material. That said, and without having carried out a thorough market analysis the market for recycled crushed glass would appear to be increasing in Victoria for the following reasons;

- Large infrastructure projects within the Melbourne Area
- Increase in allowable recycled glass as per registered VicRoads design mixes, (as indicated by Alex Fraser Group)
- Increasing desire of contractors to have a ISCA , (Infrastructure Sustainability Rating Scheme) rated projects due to growing public awareness of environmental concerns. As an example, both the Citylink Tullamarine Freeway and WebbDock West project have been awarded an IS as-built rating of excellence
- At some point in time, limited supply of quarry material, particularly in the south and east of Melbourne, (as per Sustainability Victoria business case 2015) is also expected to result in increasing market demand

Evidence of the growing market can possibly be found in the recently commissioned Alex Fraser glass recycling plant in Laverton. This plant is capable of separation of metal, paper and plastics from the glass and at 150 000 tonnes per year is understood to be a first in Victoria for a plant of this scale and type. Crushed glass will be used for both base course and sand applications.

D7 SPRAY SEALS

D7.1 General

Spray seals are a system used in road surfacing. Spray sealing is achieved by spraying a thin film of bituminous binder on to a road surface, and then covering it with a layer of aggregate (Boral 2011).

This section of the report addresses the type of binder used during this process.

Cutback Bitumen is the most commonly used type of spray seals. Bitumen is 'cutback' by adding controlled amounts of petroleum distillates such as kerosene to reduce the viscosity of the bitumen temporarily so it can penetrate pavements more effectively or to allow spraying at temperatures that are too cold for successful sprayed sealing with neat bitumen. Typically, a single application of the appropriate cutback bitumen is sprayed onto the primed pavement onto which aggregate is laid.

Sustainability considerations

Cutback bitumen needs to be kept at high temperatures (160–180 °C). The evaporation of kerosene is an energy intensive process and it emits greenhouse gases. Contractors working under these conditions are exposed to a variety of safety hazards such as burns, explosions, etc. The fumes and odours released from the solvent have also been known to affect the workers making them feel nauseous.

Good weather conditions during construction and relatively high pavement temperatures for at least one month are necessary to ensure that adequate curing of the emulsions is achieved (Austroads 2008).

Bitumen emulsion

Bitumen emulsions are an alternative binder to a standard cut-back binder. Bitumen emulsions are made up of three components: bitumen, water and emulsifier. It is a two phase system consisting of two immiscible liquids (AustRoads 2008).

Bitumen emulsions have traditionally been less preferred to hot cutback bitumen because:

- Hot cutback bitumen is more cost-effective as it eliminates the manufacturing process between the refinery and road
- Bitumen emulsions have 'run off' (low viscosity) problems
- There is a delay between application and opening to traffic to ensure that the emulsion has broken
- There is general lack of knowledge and understanding of emulsion technology

Current high binder content emulsions, emulsified polymer modified binders (PMEs), tailored emulsifying agent etc. have managed to overcome some of the problems mentioned above. High binder content bitumen emulsions address the 'run off' and slow breaking problems. PMEs provide the same elastic properties as conventional PMBs as well as having the decreased viscosities and low spraying temperatures of an emulsion. PMEs, with their lower viscosity, are better than conventional PMBs at coating the sealing aggregate and so reduce the risk of early aggregate stripping problems. The lower operating temperatures also reduce the risk of potential damage to the product during storage and handling. High binder content PMEs also reduce the amount of polymer additives and use up to 30% less water. Unlike cutback bitumen which needs to be kept at high temperatures, bitumen emulsions are water based.

Two of the main concerns faced by road works when using bitumen emulsions were the 'runoff' problem and the necessary delay during breaking. The main advantages are the possibility of extending the sealing season, lower energy consumption, increased recycled content through the use of old tyres as the polymer, and, particularly, the elimination of kerosene use which is seen as detrimental to the environment.

Reduction of greenhouse gases is often cited as a major advantage of emulsions but some studies have suggested that the benefits may be reduced because of the energy involved in emulsion production and the transport of the extra water incorporated in emulsions to the work site.

Emulsions can provide an alternative to the use of hot cutback bitumen but currently in Australia they are typically only used as an alternative treatment during the cooler months.

Emulsions have historically not been preferred in Australia because of the loss of aggregate and tight traffic control required at the early stage of sealing.

The tables below illustrate the sustainability information for bitumen emulsion.

Table D7.1 Core Indicators, Bitumen Emulsions

Indicator	Information
Embodied Carbon	Less embodied carbon (approximately 60% less) due to the heating required for hot cutback bitumen.
Recycled content	Recycled tyres and rubber materials are used in the manufacturing process of Poly Modified Binders (PMB)
Cost	Generally cost more, however use of recycled material can reduce the cost
Geographic/regional/ market availability	Available in regional Victoria

Table D7.2 Supplementary Indicators, Bitumen Emulsions

Indicator	Information
Water usage performance	30% reduction in water usage in production
Pollutants (other than greenhouse gas):	Reduced use of solvents
Reusability/Adaptability /Recyclability:	Not reusable, but does not impact the reusability of asphalt
Practical applicability:	Road tests carried out in Australia and New Zealand between 1993 and 1997 revealed good performance of the material and no visual differences with seals constructed with standard distillate pre coated aggregates. Whilst there is a need to tightly control traffic during the initial stages to minimise the early loss of aggregate, emulsion sprayed seals generally have equivalent performance to cutback bitumen and when applied under cooler and wetter conditions generally perform better than cutback bitumen applied under the same conditions.

D7.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D7.3 Core indicators, Spray Seals

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Bitumen cutback	0	0	5	5
Bitumen emulsions	3	1	34	5

Table D7.4 Supplementary indicators, Spray Seals

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Bitumen cutback	1	0	0	4
Bitumen emulsions	4	3	0	3

The final weighted scores are shown below.

Table D7.5 Weighted scores, Spray seals

Material	Weighted Score (out of 100)
Cutback bitumen	45
Bitumen emulsion	52

D7.3 Discussion

Using refined oil as a key ingredient, and a requirement to be kept at a high temperature during application, cutback bitumen has a high embodied energy. There is an opportunity for improving construction project sustainability through consideration of cutback bitumen alternatives.

The alternative discussed here, bitumen emulsion, does not require such high heating temperatures and has lower embodied carbon. It also has the potential to incorporate recycled materials in the product manufacture.

CRM

CRM has traditionally been used in spray seal binders since the 1970's. One of the reported limitations of CRM is that its use is limited to areas close to the point of manufacture, which restricts its application for remote projects. Over long distance, settlement of the crumb rubber particles can occur. SAMI Bitumen Technologies have developed a technique to provide a more stable CRM binder suitable for long distance transport. As indicated in a recent roadsonline article, SAMI supplied approximately two million litres of CRM binder to a site 1100 km from their manufacturing facility in Brisbane without rubber particles dropping out of suspension or degradation of the binder occurring.

D7.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D7.6 Manufacturers, Alternative Spray Seals

Bitumen Emulsions	Comments
Boral	Readily available and mixed within Victoria
Cranes Asphalting and Bitumen Sealing	Victorian based company
Fulton Hogan	Available across Victoria
SAMI Bitumen Technologies	Widely available

Bitumen emulsions are a specialist area that has a niche market across Australia. The identified suppliers of bitumen emulsion are large companies that can readily supply to regional Victoria.

A small number of medium Victorian based bitumen suppliers were called during this research to enquire about their products. Regarding Bitumen emulsions, all companies referred the caller to one or more of the above listed suppliers.

The market for this material is strong due to the long-reach of the major suppliers; however, market development and entry by smaller suppliers should be encouraged.

D8 CONCRETE PAVEMENT REHABILITATION

D8.1 Pavement breaking technology

A recent venture, Concrete Pavement Recycling Pty Ltd (CPR) have imported an Antigo Multi-Head Badger Breaker, (MHB) into Australia in response to the pending challenges of remediation works to ageing rigid concrete pavements across the country. The MHB comprises a number of 550 to 800kg hammers that can fracture or break or break concrete while moving along the road at walking pace. By utilising the MHB, CPR can offer the following services;

- Rubblisation
- Crack and Seat
- Break and Seat
- Break for removal

Rubblisation involves fracturing the concrete and into small pieces and rolling to eliminate slab subsidence and compensate for weak subgrades and base course materials.

Crack and seat involves cracking the concrete slab to reduce its effective length and then seating, which could be via roller or opening the road to traffic

Break and seat is similar to crack and seat, but involves more energy to sever reinforcing steelwork. Typically, proof rollers would be required to seat the broken concrete

All three methods require the application of an asphalt overlay. The obvious benefits of these technologies are that the concrete pavement does not require removal, hence minimising costs and energy usage associated with removal and disposal, and materials required to repave the road. This technology has been in place since the 1980's in the United States but Australia has been a slow adaptor

Break for removal involves breaking down the concrete to customer specified sizes for removal by the customer where onsite crushing and screening can take place for immediate reuse as a sub grade aggregate.

Figure D8.1. – Example of Rubblisation

Antigo Construction, Inc 2014

The tables below illustrate the sustainability information for Concrete Pavement Rehabilitation

Table D8.1 Core Indicators, Concrete Pavement Rehabilitation

Indicator	Information
Embodied Carbon	Embodied carbon is energy used in recycling process only which is considerably lower than a full highway subrgrade replacement process.
Recycled content	100% recycled usage for reuse component. %age in final road differs depending on road construction method and reuse method.
Cost	On site waste used, no truck away costs, no truck in costs for virgin aggregate, no spreading costs in some methods. Equipment delivery and return costs may be considerable and impact on small jobs especially.
Geographic/regional/ market availability	To be explored. Single contractor for this technology at this time.

Table D8.2 Supplementary Indicators, Concrete Pavement Rehabilitation

Indicator	Information
Water usage performance	N/A
Pollutants (other than greenhouse gas):	Varies with method. If lifting, crushing and replacement after cracking is used then this depends if electric or engine driven on site crushers are used.
Reusability/Adaptability /Recyclability:	Fully recyclable
Practical applicability:	Has been used since the 1980's in the United Sates and is proven technology

D8.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D8.3 Core indicators, Concrete Pavement Rehabilitation

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Demolish, remove to landfill, reform with fresh aggregate	0	0	1	5
Rublisation	4	4	4	1
Crack and seat	4	4	4	1
Break and seat	3	4	4	1
Break for Removal**	2	5	2	1

* Ratings compared to demolition, removal to landfill, reform with fresh aggregate.

Ratings also assume similar bearing capacities achieved for the four methods mentioned, hence similar coverage of asphalt concrete.

** Assumes fragmented concrete is fully recycled.

Table D8.4 Supplementary indicators, Concrete Pavement Rehabilitation

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Demolish, remove to landfill, reform with fresh aggregate	0	2	5	4
Rublisation	4	4	5	4
Crack and seat	4	4	5	4
Break and seat	4	4	5	4
Break for Removal	0	4	5	4

The final weighted scores are shown below.

Table D8.5 Weighted scores, Concrete Pavement Rehabilitation

Material	Weighted Score (out of 100)
Demolish, remove to landfill, reform with fresh aggregate	35
Rublisation	69
Crack and seat	69
Break and seat	66
Break for Removal	56

D8.3 Discussion

The benefits of this technology are clear where it is applicable. Avoidance of removal and full replacement of substrate – along with simplification of resurfacing are significant improvements if the technology can be established for the Australian market.

D8.4 Market assessment

According to a recent Road Infrastructure article, CPR are currently working with AAPA to set up demonstrations of the technology in Queeensland, New South Wales and Victoria. Given the large number of existing concrete roads in Queensland and NSW, including sections of the Hume Freeway, Pacific Motorway there would appear to be a market for such technology. However trials and acceptance of the cracking, breaking and rublising methods by the various Council and road authorities will presumably need to occur, along with specifications and regulations prior to widescale adoption of the technology within the industry.

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Concrete Pavement Rehabilitation	Comments
Concrete Pavement Rehabilitation (CPR)	Based in NSW and Queensland. Currently the only known organisation in Australia to offer pavement rehabilitation using the multi head breaker technology

D9 SOLAR POWERED LIGHTING

D9.1 General

Portable solar lighting towers are starting to appear as an alternative to diesel power lighting towers on road construction projects with the obvious benefits being the elimination of diesel usage, noise and fumes. As an example, Newcastle based organisation Solar Hire has currently supplied five solar powered lighting towers to the Sydney North Connex Road Project for the M2 tunnel.

Allight Sykes have recently released their URBAN Solar LED Metro lighting tower onto the market. This product comprises a panel charging an array of batteries to power a 4x100 watt LED system. Allight Sykes have indicated that the tower is able to run for five consecutive days of ten hours per night in poor sunlight conditions. Provision is also provided for charging via a mains input if required.

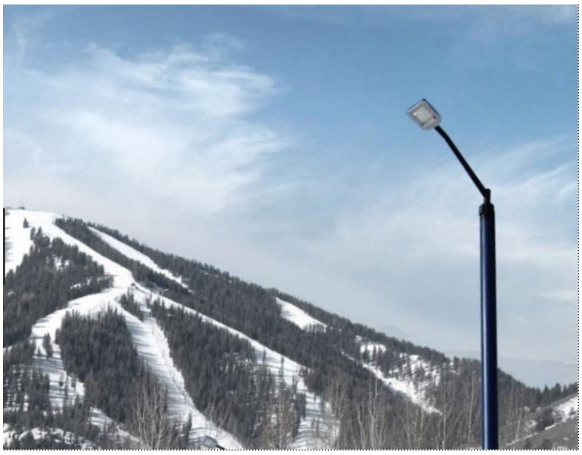
Current solar powered street lighting comprises of a deep cycle storage battery, solar panels and outreach arm to allow adjustment of the panel angle, LED lights and a controller. The controller includes such features as detection of battery charging levels to prevent over charging, activation in low light conditions, and operating timers etc. The major benefits are elimination of mains cable connection costs, and grid power usage costs. Other benefits can include ongoing lighting in the event of mains power black outs and emergency situations.

Figure D9.1 Solar power street lighting – panel type

Orion Solar 2015

Another version comprises of a thin film solar collector wrapped around the pole which negates the need for the outreach arm and associated design challenges due to wind effects. These were trialled by Randwick Council back in 2010. One such supplier of this equipment, Inovus has indicated these types have been installed in Maroubra, Lake Macquarie, Wangrah Creek and Penrith, (all in NSW).

Figure D9.2 Solar powered street lighting – wrapped type



Based on various sources, as of late 2018 there has been an uptake by over a 100 councils within Australia of energy efficient lighting projects. Victoria would appear to be the leader in this area with 68 out of a total of 79 councils implementing greener lighting technologies. The majority of these works are in the area of LED upgrades. Solar street lighting is now emerging as a new technology but based on an initial overview of the market it was difficult to quantify the level of uptake by Councils across the country. It is expected, although has not been fully quantified that solar lighting would generally be more cost effective for new street lighting installations located away from existing poles and wires infrastructure rather than for existing street lighting installations already serviced from grid power. The differences are due to the differential between grid connection costs and the cost of batteries, panels, and battery replacement at end of life. There are no definitive studies of the life cycle cost of solar powered LED versus a grid powered installation for Australia however some analyses for other countries indicate short payback periods. The result of the business case is obviously related to the length and difficulty of cabling / grid connection amongst other costs and would vary on a project by project basis.

The tables below illustrate the sustainability information for Solar powered street lighting

Table D9.1 Core Indicators, Solar Powered Street Lighting

Indicator	Information
Embodied Carbon	Lower where the site is sufficiently remote. Large scale applications over time will also reduce public infrastructure demands in grid sizing
Recycled content	Batteries and electronic components are fully recyclable where the facilities exist.
Cost	Appears to be a lower life cycle cost where the site is sufficiently remote. For sites where grid connection and cabling is already available more work is required to make a determination for Australia
Geographic/regional/ market availability	Available in all regions

Table D9.2 Supplementary Indicators, Solar Powered Street Lighting

Indicator	Information
Water usage performance	N/A
Pollutants (other than greenhouse gas):	Generally N/A, however battery and electronics production may contribute to heavy metal pollutants but the significance is yet to be determined.
Reusability/Adaptability/ Recyclability:	Repositioning / reuse potential for any functional unit is high. Battery replacements will extend remaining components life and ensure lifetime of LED is achieved.
Practical applicability:	Particularly suited to areas where no mains power is available. Possibly useful where mains power is interrupted or damaged and repair is difficult or costly.

D9.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D9.3 Core indicators, Solar Powered Street Lighting

Product	Carbon	Recycled content	Cost	Geographic /regional/market availability
Solar street lighting in remote location	5	3	4	5
Grid connected street lighting in remote location	0	3	2	5

Table D9.4 Supplementary indicators, Solar Powered Street Lighting

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/ Adaptability/ Recyclability	Practical applicability
Solar street lighting in remote location	4	2	5	4
Grid connected street lighting in remote location	1	2	5	2

Solar panels in principle can be recycled but due to long life span and relatively new addition to the market, recycling infrastructure is not widely available. These ratings assume infrastructure will be In place in the future

The final weighted scores are shown below.

Table D9.5 Weighted scores

Material	Weighted Score (out of 100)
Solar street lighting in remote location	83
Grid connected street lighting in remote location	50

D9.3 Discussion

At this point in time, solar lighting would therefore appear to lend itself to parks, foot paths, public spaces and sports grounds etc and potentially new road developments but not so much existing lighting for established road infrastructure.

With regard to roads it has been noted that Main Roads Western Australia has produced a policy document on LED Solar Powered Lighting (Document No. D16#649500 last amended in June 2016)

D10 TIMBER

D10.1 General

Timber is a commonly used construction material in the building industry and has been used for thousands of years due to its easy assemblage and structural characteristics. It is a renewable, organic material made from a natural composite of cellulose fibres (which are strong in tension) embedded in a matrix of lignin which resists compression (*The Cambridge Illustrated Glossary of Botanical Terms*. Cambridge University Press)

The production of wood products uses less energy compared with some other building materials such as concrete or steel (NaturallyBetter.com). The use of timber as a construction material has additional environmental benefits due to its simpler production process and also its recyclability.

Sustainability considerations

Continued demand for timber results in continued requirement for native forest clearing. The Australian Forestry Standard (AFS) state that only 6% of Australia's 147 million hectares of native forests is public forest potentially available for timber harvesting, and that timber is harvested from about 1% of these public native forests each year.

Plantation (AFS) Timber

Plantation timber is a common material used extensively throughout the construction industry.

Victoria's timber plantation estate is around 451,500 hectares and accounts for more than 20 per cent of Australia's plantation forest estate (ABARES 2012).

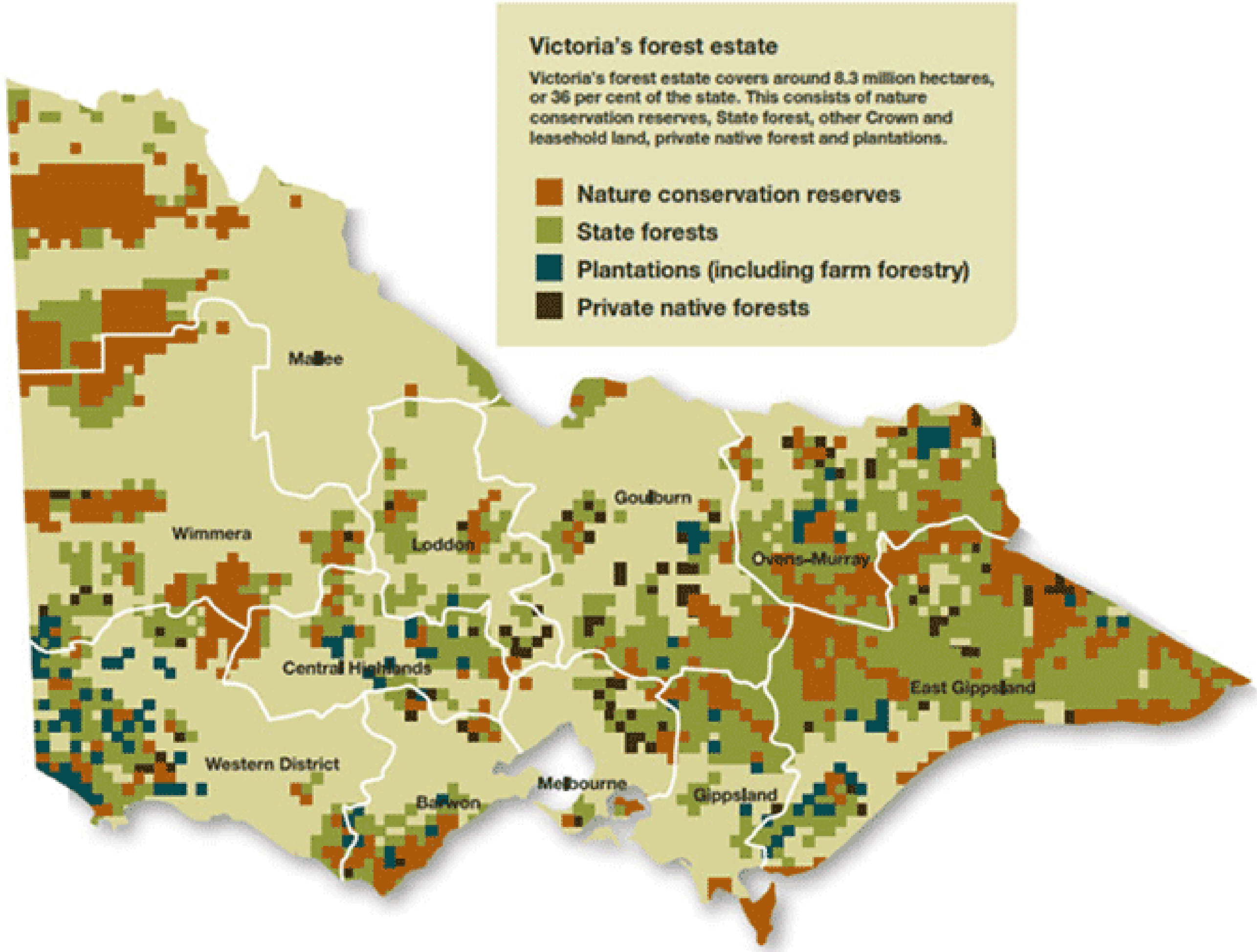
There are currently two major plantation types across Victoria – Pine and Eucalypt plantations. The pine plantations (an exotic species) are grown for softwoods and the eucalypts (native) are grown for hardwoods.

Due to the mono-cultural structure of tree plantations, the impacts of clearing a stand of plantation timber as opposed to native forests are far less in terms of ecosystem and habitat destruction.

Australian Forestry Standard (AFS) Plantation Timber comes from certified plantations which meet strict criteria in regards to quality and sustainability. An AFS certification indicates that the timber was grown in a properly managed plantation in which "the plantation owner meets the economic, social, environmental and cultural criteria and requirements that support the sustainable management of forests for wood production" (Sustainable Forestry Management, Australian Forestry Standard Australia).

Figure D10.1 shows the geographic spread of plantations throughout Victoria.

Figure D10.1 Location of forests and plantations in Victoria



(Victorian Department of Primary Industries 2012)

Whilst it is generally preferable to use plantation timber, some negative environmental impacts include:

- In some cases native forests are cleared to make way for the initial planting of tree plantations.
- Most tree plantations provide little-to-no habitat for native fauna species
- Tree plantations often consist of exotic tree species which are not endemic to the locality

The tables below illustrate the sustainability information for AFS (plantation) timber.

Table D10.1 Core Indicators, AFS Timber

Indicator	Information
Embodied Carbon	In the case of plantation timber where forests are harvested and then replanted, the timber becomes carbon neutral. The growing tree will take up as much CO2 as the harvested one will eventually release
Recycled content	There is no recycled content in timber.
Cost	AFS timber will generally cost slightly more than non-certified timber.
Geographic/regional /market availability	AFS timber is available locally in Victoria; however there is not currently sufficient plantation timber in Victoria to meet demand. As a result, Victoria currently imports a significant number of timber products from native forest and plantation harvesting overseas

Table D10.2 Supplementary Indicators, AFS Timber

Indicator	Information
Water usage performance	AFS Certification includes requirements for the plantation manager to effectively manage water (e.g. minimise pollution)
Pollutants (other than greenhouse gas):	AFS Certification includes requirements designed to minimise any pollutants
Reusability/Adaptability/ Recyclability:	All timber products are 100% recyclable
Practical applicability:	AFS timber products are useable in all applications virgin timber is used

Recycled timber

Recycled timber is timber that has been reclaimed from demolished buildings, bridges, and other structures. In contrast to other construction materials, timber can be reused without requirement for remanufacture. However, it is possible to re-mill or re-finish, improving the physical appearance.

It may be considered to be the most sustainable option as it replaces the need for tree harvesting and requires no production process which dramatically decreases land clearing and pollution outputs.

Widespread adoption of recycled timber is still constrained by a few limitations in regards to quality and strength. In the construction industry it is often perceived as quicker and easier for the builder to use 'new' wood instead of spending the time and money to acquire the exact sizes and types of recycled timbers needed for a specific construction.

The availability of recycled timber fluctuates which is generally not the case with 'new' timber products. This constraint however is decreasing as a result of advancements in processing methods (i.e. de-nailing and pest treatments).

Recycled timber benefits from its image as an environmentally friendly product, with consumers commonly believing that by purchasing recycled wood the demand for "green timber" will fall and ultimately benefit the environment.

The tables below illustrate the sustainability information for recycled timber.

Table D10.3 Core Indicators, Recycled Timber

Indicator	Information
Embodied Carbon	The amount of embodied energy will vary, depending on the original application and the demolition requirements, as well as transport requirements. However, it would generally be lower than for virgin timber.
Recycled content	Recycled timber utilises 100% recycled materials
Cost	Costs for recycled timber vary widely, depending on the type of timber and the intended use. It is however, generally cheaper than the virgin timber equivalent.
Geographic/regional/ market availability	Available in regional Victoria

Table D10.4 Supplementary Indicators, Recycled Timber

Indicator	Information
Water usage performance	No water is used in timber reuse/recycling (unless the product is retreated).
Pollutants (other than greenhouse gas):	No pollutants are emitted in timber reuse/recycling (unless the product is retreated).
Reusability/Adaptability/ Recyclability:	Timber is 100% recyclable
Practical applicability:	Recycled timber is useful for all applications virgin timber is used; however, the costs for recycled timber vary widely, depending on the type of timber and the intended use.

D10.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D10.5 Core indicators, Timber

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Virgin timber	0	0	5	2
Plantation timber	3	0	4	5
Recycled timber	4	5	5	5

Table D10.6 Supplementary indicators, Timber

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Virgin timber	2	2	-	4
Plantation timber	3	4	-	4
Recycled timber	4	4	-	3

The final weighted scores are shown below.

Table D10.7 Weighted scores, Timber

Material	Weighted Score (out of 100)
Virgin timber	38
AFS plantation timber	63.5
Recycled timber	92

D10.3 Discussion

Whilst the production of wood products uses less energy and therefore embodied carbon than the majority of other construction products, the use of virgin timber (native forest) has the potential to negatively impact on native ecosystems and reduce biodiversity.

The two alternatives discussed here, plantation timber and recycled timber, are both reasonably available throughout Victoria and comparable in terms of cost.

From a sustainability perspective, these alternatives offer the benefit of either being recycled, as with the recycled timber, or, in the case of the plantation timber, can potentially minimise the impact on ecosystems and habitat during harvesting, particularly when certified product is used.

D10.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D10.8 Manufacturers, Alternative Timber

Australian Forestry Standard Timber	Comments
There are a large number of suppliers of Certified timber within Victoria Neighbouring states can also provide a strong supply of certified timber Specific suppliers have not been listed here	
Recycled Timber	**Comments**
Australian Recycled Timber	VIC
Urban Salvage	VIC

There are a large number of suppliers of certified plantation timber and recycled timber within Victoria. Ideally, the closest supplier to the site would be selected to provide the product.

This is a strong market, and some concern has been raised about overdemand. That is, if the product needs to be imported from other states of Australia or internationally, some of the sustainability benefits of the certified timber will be reduced.

D11 STEEL

D11.1 General

Steel is an alloy of iron ore and carbon (coke from coal) and usually contains between 0.2% - 1.5% carbon by weight. Often, other metals are added to give steel a particular property, for example, chromium and nickel is added to make stainless steel (BlueScope Steel n.d.).

Scrap metal is an important part of steel's composition as it maintains the thermal balance of the steelmaking and also makes steel one of the few materials in the world to have a guaranteed recycled content (BlueScope Steel n.d.).

The two most common methods for steel making are:

- Basic Oxygen Steelmaking – The traditional method primarily using raw materials
- Electric Arc Furnace Steelmaking – A newer method primarily using scrap metals

(Strezov and Herberston 2006)

Sustainability Considerations

As is mentioned above, most steel products on the market will contain some percentage of recycled steel. The level of inclusion depends largely on the method used for manufacturing the product.

Steel extraction and production is an energy intensive process, especially when using raw materials as the primary feedstock. Most steel products require significant transportation because of the small number of steel production sites across Australia. To give an indication of the energy intensive production process, the transportation only contributes about 2% of the overall carbon impact (Strezov and Herberston 2006).

This section considers recycled steel and steel produced with Polymer Injection Technology as alternatives to standard steel.

Recycled Steel

Steel is easily recycled by separating it steel from other materials. It is then melted and reshaped for a new application. From an environmental point of view, steel recycling has a significant impact on the reduction of CO_2 emissions. There are a number of key benefits associated with recycling steel for reuse including:

- Every tonne of recycled steel saves 1131kg of iron ore, 633kg of coal and 54kg of limestone
- Avoid air and water pollution
- Save landfill space, as steel can be recycled indefinitely
- Conservation of energy and resources
- The tables below illustrate the sustainability information for recycled steel.

Table D11.1 Core Indicators, Recycled Steel

Indicator	Information
Embodied Carbon	Recycled steel has approximately 15-20% less embodied carbon than virgin steel
Recycled content	100% recycled

Indicator	Information
Cost	Significant cost savings
Geographic/regional/ market availability	This is a very common product, most steel contains recycled content

Table D11.2 Supplementary Indicators, Recycled Steel

Indicator	Information
Water usage performance	40% reduction in water use 76% reduction in water pollution
Pollutants (other than greenhouse gas):	86% reduction in air pollution 76% reduction in water pollution
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Recycled steel demonstrates the same properties as virgin steel

Polymer Injection Technology

Polymer Injection Technology is a patented process which partially substitutes the use of coke with polymers (like rubber) as an alternate carbon injectant to produce foaming slag Electric Arc Furnace (EAF) Steel.

A Professor from the University of New South Wales first developed the idea of using polymers as a partial Coke replacement in EAF facilities. This lead to a three year technology development and testing programme in partnership with Onesteel at the Sydney facility (World Steel Association 2010). The University of NSW holds the patents to this product and has granted Onesteel the exclusive right to sub-licence this technology for use around the globe (World Steel Association 2010).

This innovation offers an opportunity to improve steel cost efficiency while having a positive impact on the environment through energy savings and recycling polymers. Polymer injection of a rubber sourced from used vehicle tyres is now in commercial use at two EAF facilities in Sydney and Melbourne.

The following numbers provides a sample of results achieved at the Laverton Steel Mill during a recent trial under controlled condition:

- Reduced specific electrical energy consumption
- Reduced carbon injectant of approximately 16%
- Increased furnace productivity (tonnes per minute) of 2%

(Onesteel 2009)

Reinforcing steel manufactured using polymer injection technology has been included in the Green Building Council of Australia's GreenStar Scheme.

The tables below illustrate the sustainability information for polymer injection technology.

Table D11.3 Core Indicators, Polymer Injection Technology

Indicator	Information
Embodied Carbon	Data has not yet been quantified for this material; however suppliers report a decrease in electricity use and heat requirements which would result in a reduction of embodied carbon.
Recycled content	Potential to recycling more than 285,000 used passenger tyres per year Recycled steel is used during the process (up to 60%)
Cost	Reduction in cost
Geographic/regional/ market availability	Available in Melbourne by One Steel

Table D11.4 Supplementary Indicators, Polymer Injection Technology

Indicator	Information
Water usage performance	Information not available
Pollutants (other than greenhouse gas):	Reduced NO_X SO_X and CO emissions
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	This product can be used for all applications where regular reinforcing steel is used

D11.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D11.5 Core indicators, Steel

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Steel	0	3	4	5
Recycled steel	3	5	5	5
Polymer Injection Technology	2	4	4	4

Table D11.6 Supplementary indicators, Steel

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Steel	0	0	5	4
Recycled steel	3	3	5	4

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Polymer Injection Technology	0	3	5	4

The final weighted scores are shown below.

Table D11.7 Weighted scores, Steel

Material	Weighted Score (out of 100)
Structural steel	61.5
Recycled steel	89
Polymer Injection technology	71

D11.3 Discussion

Due to the high embodied carbon present in virgin steel, an opportunity exists throughout the construction industry to significantly reduce the embodied carbon in construction projects by considering alternatives to virgin steel. An increase in the use of recycled steel will have benefits not only in terms of reducing embodied carbon, but also in terms of:

- Reduced costs
- Reduced water use
- Reduced potential for pollution

D11.4 Market assessment

Recycled steel is a very common product, therefore a list of manufacturers and their brand has not been provided

Due to the high value of steel, recycling is generally optimised. Most steel producers will provide steel with at least 60% recycled content.

It is important that suppliers are questioned about the recycled content of their product, and if given an option, Councils should select the product with the highest recycled content.

The market is largely controlled by a small number of dominant steel producers. Where possible, local distributers of the product should be targeted for supply.

D12 PAVERS (CLAY)

D12.1 General

Clay pavers or bricks have been used for houses, parking areas and general paving for centuries. The standard clay generally consists of Silica, Alumina, Iron oxide, magnesia, lime, Alkali and Organic Matter (Engineering Materials 2011). The specific composition of the clay will vary depending on where the clay is extracted and at what depth.

Whilst, the basic principle of clay product manufacturing is fairly uniform, there are slight variances depending on the plant and production company. Generally, clay products are produced by mixing ground clay with water, which forms the clay, before the product is dried and fired. The firing process can take 10-40 hours (depending on the kiln type and manufacturer) and will vary between temperatures of 150 degrees Celsius to 990 degrees Celsius (depending on the process stage) (Brick Industry Association 2006)

Sustainability Drivers

Given the strong stock of clay resources present around the world, the primary sustainability concern regarding the use of virgin clay products is not related to depletion of natural resources. Rather, the emphasis is on the manufacturing process, and the high amount of energy consumed by extensive kiln firing.

The two alternative products identified, significantly reduce the carbon impact:

- Low carbon pavers
- Recycled clay pavers

Low carbon pavers

Low carbon pavers are pavers that use waste material and clay to create a functional 'clay' paver. There are a number of waste materials that could be used in this process, however the below listed are the current sources on the market:

- Timber waste, discarded timber, sawdust etc.
- Industrial waste, slag or fly-ash
- Clay waste from manufacturing process

(Timbercrete n.d and Claypave 2012.)

These pavers are fired and manufactured through the same processes as standard clay pavers; however, the blend is altered to include the waste material. The blend for this alternative is largely dependent on the supplier, as there is no standard or restrictions on performance that prescribe the composition of the paver.

Performance of these pavers has been shown to meet requirements for commercial use.

The tables below illustrate the sustainability information for low carbon pavers.

Given the composition variety in the available products, the below information provides an indication of the environmental benefits associated with a clay paver that uses 80% recycled material (fly ash and waste pavers), and sustainable energy and water measures during the manufacturing process.

Table D12.1 Core Indicators, Low Carbon Pavers

Indicator	Information
Embodied Carbon	Low carbon pavers can have up to 90% less embodied carbon than clay pavers (supplier and mix dependent).
Recycled content	80% recycled content
Cost	25% reduction in manufacturing costs A local company in Australia stated that the pavers would be on parity with virgin clay pavers but the overall project cost is reduced as the paver is lighter and easier to install
Geographic/regional/ market availability	This product is relatively limited Small number of examples are located in Victoria

Table D12.2 Supplementary Indicators, Low Carbon Pavers

Indicator	Information
Water usage performance	82% reduction in water usage, without extraction of virgin materials
Pollutants (other than greenhouse gas):	Information not available Expected that pollution would be reduced as extraction of virgin materials is reduced
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Performance of the alterative pavers has been comparable to clay pavers in commercial and residential scenarios.

Recycled clay pavers

There are obvious benefits associated with using recycled clay pavers:

- Conservation of natural resources
- Significant reduction in carbon emissions and impact
- Cost efficiency, as the primary cost is to the supplier
- Limited reprocessing (dependant on supplier and method for manufacturer).
- There are two potential methods for clay paver recycling:

1. **Method 1:** Waste material from the manufacturing process or rubble from construction sites can be ground back to a suitable state for inclusion in the manufacture of new clay products; or
2. **Method 2:** Waste bricks in good condition can be resold, after some cleaning, back into the market

Reprocessing brick rubble obtained through the manufacturing process or from Construction and Demolition (C&D) practices (Method 1) does not present the same environmental benefits as reusing bricks/pavers in good condition (Method 2). The disparity between the environmental benefits is mainly due to the amount of reprocessing required. Recycling brick rubble requires the ground material is manufactured using the same process as is described in **Clause D 12.1**, however, reusing waste pavers in good condition would simply require some cleaning, polishing and re-shaping.

The market in Victoria primarily focuses on method 2, whilst brick rubble (as described by Delta/Boral) is most often used as an aggregate for infrastructure and construction. The tables below illustrate the sustainability information for recycled clay pavers, assuming (unless stated otherwise) that method 2 is used for recycling the clay pavers.

Table D12.3 Core Indicators, Recycled Clay Pavers

Indicator	Information
Embodied Carbon	At least a 43% reduction in embodied carbon (this would represent the worst case CO2 reduction, assuming a high level of reprocessing)
Recycled content	100% recycled
Cost	At least 20% reduction in cost
Geographic/regional/ market availability	Recycled bricks and pavers are widely available Installers are available in regional Victoria

Table D12.4 Supplementary Indicators, Recycled Clay Pavers

Indicator	Information
Water usage performance	Significant water savings by eliminating the extraction process for virgin materials
Pollutants (other than greenhouse gas):	99% less SOx, 98% less NOx
Reusability/Adaptability/ Recyclability:	100% recyclable (as rubble or clean brick)
Practical applicability:	The mechanical and functional performance of the recycled product is equivalent to virgin clay pavers

D12.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D12.5 Core indicators, Clay Pavers

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
New clay pavers	0	0	4	5
Low carbon pavers	4	4	5	3
Recycled pavers	3	5	5	5

Table D12.6 Supplementary indicators, Clay Pavers

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
New clay pavers	0	0	-	4
Low carbon pavers	3	4	-	4
Recycled pavers	3	4	-	4

The final weighted scores are shown below.

Table D12.7 Weighted scores, Clay Pavers

Material	Weighted Score (out of 100)
Natural clay	39
Low carbon pavers	81.5
Recycled clay	87.5

D12.3 Discussion

Clay pavers (or bricks) are another item with high embodied carbon. This is a result of the energy intensive nature of the extractive and processing activities as well as transport requirements.

The two alternatives discussed here, low carbon pavers and recycled clay pavers, both have significantly lower embodied carbon and can be sourced for a comparable (or cheaper) cost.

From a sustainability perspective, these alternatives offer the added benefit of using less process water in manufacture and making use of recycled materials. Whilst the recycled pavers are reasonably available throughout Victoria, there is currently only limited availability of the low carbon pavers.

D12.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D12.8 Manufacturers, Alternative Clay Pavers

Low Carbon Pavers	Comments
Timbercrete, Timbercrete pavers	Product is available in Victoria through manufacturers and distributers The product has currently only been used for residential purposed, but the opportunity and applicability of this product to the commercial sector is encouraged by the company and the products characteristics
Claypave, Claypave pavers	Australian owned company, pavers distributed from multiple locations across Victoria
Vecor, Vecor Tiles	NSW based company
Recycled Clay Pavers	**Comments**
Ecobricks Beaver Bricks Bricks Melbourne Uneeda Bricks Paddy's Bricks Used Bricks Melbourne	All listed suppliers are Melbourne based companies The companies are of various sizes but all collect, clean and resell waste bricks for new projects Damaged bricks are not re-sold through the same market

There is a strong market within Victoria for recycled bricks. It is anticipated that the above list of suppliers is a very select few. Given the strong market, the IDM Group should source recycled bricks from the closest available supplier.

The cleaning and treatment processes used by each supplier should also be investigated upon request of service to ensure that efficient processes are being used.

Low carbon pavers can include the use of any number of waste materials. The most common has been timber waste and waste from industrial processes (slag and flash). The composition, and extent of waste material used within the paver will be largely dependent on the supplier. It is important that suppliers are encouraged to optimise the use of waste materials in their product, which may also encourage new/existing companies to include use of waste materials within their products.

D13 PAVERS (STONE)

D13.1 General

Stone pavers have been used for roads, street and pathways construction for many centuries. Over time, many different systems of laying and interlocking have been developed using naturally occurring materials including sandstone, bluestone, granite, marble, slate, limestone and others. There have also been composites of natural and manufactured stone pavers combining natural stones with concrete, resins and other binding agents.

Sustainability drivers

While natural stone pavers present a high level of sustainability for use in pathways and hard surfaces, there are other alternatives which minimise manufacture and processing, or reuse existing post-consumer reject materials and waste products.

Permeable paving provides a range of sustainable materials and techniques for permeable pavements with a base and sub-base that allow the movement of stormwater through the surface. In addition to reducing runoff, this effectively traps suspended solids and filters pollutants from the water. Examples include roads, paths, lawns and areas subject to light vehicular traffic, such as car/parking lots, cycle-paths, service or emergency access lanes, road and airport shoulders, and residential sidewalks and driveways.

Although some porous paving materials appear nearly indistinguishable from nonporous materials, their environmental effects are qualitatively different. Porous asphalt, paving stones or concrete pavers allow stormwater to percolate and infiltrate the surface areas, traditionally impervious, to the soil below.

Resin-Bound Permeable Pavers (RBPPs)

Resin Bound Porous Pavers (RBPPs) provide a water-saving and pollution-minimising alternative to traditional asphalt pavements.

RBPPs can generally be used for pedestrian and low-medium traffic areas.

RBPPs allow water to seep through the resin bound aggregate into a free-draining structural pavement layer (that also traps contaminants and pollutants) and then either into the stormwater system, a detention system or to the natural soil beneath.

Porous pavement achieves benefits in the following areas (Shackel, 2010):

- Reduces rainfall runoff from pavement surfaces
- Reduces the size or need for rainwater retention facilities in roadworks by using the pavement itself for retention. This reduces land use
- Reduces downstream flooding
- Recharges and maintains aquifers and the natural groundwater
- Traps pollutants that would otherwise contaminate groundwater or drainage systems
- Assist in the biological decomposition of hydrocarbon contaminants

The tables below illustrate the sustainability information for RBPP

Table D13.1 Core Indicators, RBPP

Indicator	Information
Embodied Carbon	Whilst specific data is not currently available, one study concludes that approximately 50% saving in embodied carbon when a permeable pavement is used instead of a conventionally drained pavement
Recycled content	Can make use of recycled stone/aggregate/glass from on-site or off
Cost	Increase in initial cost but the whole of life is better
Geographic/regional/market availability	This is a widely available product

Table D13.2 Supplementary Indicators, RBPP

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Water usage performance</td><td>The water performance is dependent on the system selected. For example, a superior system would function as a closed loop and use the water captured in the detention system on or around the site. A lesser system filters and captures pollutants and discharges the water to the stormwater system
Regardless of the system, porous pavement assists with flood control and run-off control</td></tr>
<tr><td>Pollutants (other than greenhouse gas):</td><td>Reduction in the amount of pollutants entering the water system</td></tr>
<tr><td>Reusability/Adaptability/Recyclability:</td><td>This material could potentially be recycled for use as Recycled aggregate</td></tr>
<tr><td>Practical applicability:</td><td>RBPP can be used with limited applications.
This product has a life-span of approximately 20 years id properly maintained (cleaned to avoid clogging)
<table><tr><th>Common use for stone pavers</th><th>RBPP suitable</th></tr><tr><td>General road paving</td><td>No</td></tr><tr><td>High traffic road paving</td><td>No</td></tr><tr><td>Parking areas and hardstand</td><td>Yes</td></tr><tr><td>Footpaths</td><td>Yes</td></tr></table></td></tr>
</table>

Recycled stone pavers

Recycled stone pavers, generally obtained as construction and demolition waste, or off-cuts during the manufacture of virgin material into construction stone, can use materials such as granite, slate, and sandstone either in their natural state or as an aggregate using a binding agent. Generally, only good quality and good condition recycled stone would be reused as a paver. Reprocessing for reuse of these materials is minimal, likely to be limited to some reshaping, cleaning and polishing. Rubble, or poor quality stone would not be reused as pavers, rather, are reused as a base for asphalt, within resin-bound pavement, or as an aggregate for asphalt.

The tables below illustrate the sustainability information for recycled stone pavers.

Table D13.3 Core Indicators, Recycled Stone Pavers

Indicator	Information
Embodied Carbon	Whilst researched material reported “major savings” in embodied energy using recycled stone pavers, specific data quantifying the savings was not located.
Recycled content	100% recycled
Cost	Cost will most likely be reduced assuming that the transportation impact is minimal
Geographic/regional/market availability	This is a widely available product

Table D13.4 Supplementary Indicators, Recycled Stone Pavers

Indicator	Information
Water usage performance	Savings of at least 27l/t of material
Pollutants (other than greenhouse gas):	Not applicable
Reusability/Adaptability/Recyclability:	100% recyclable product End of life, the product can be crushed and used as aggregate
Practical applicability:	Assuming that the stone is in good condition and is not contaminated it can be used for the same applications as virgin stone blocks and pavers

D13.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D13.5 Core indicators, Stone Pavers

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Stone pavers	1	0	4	5
Recycled sandstone pavers	4	4	5	5
Permeable pavers	4	4	3	4

Table D13.6 Supplementary indicators, Stone Pavers

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Stone pavers	0	0	-	4
Recycled sandstone pavers	4	4	-	4
Permeable pavers	4	4	-	3

The final weighted scores are shown below.

Table D13.7 Weighted scores, Stone Pavers

Material	Weighted Score (out of 100)
Stone pavers	43
Recycled stone	87
Permeable pavers	74

D13.3 Discussion

As with clay pavers, stone pavers are another item with high embodied carbon due to the energy intensive nature of the extractive and reprocessing activities and transporting requirements.

The two alternatives discussed here, recycled sandstone pavers and resin-bound permeable pavers, both have lower embodied carbon and can be sourced for a comparable (or cheaper) cost. Cost is expected to be considerably less for the resin-bound permeable pavers when whole-of-life costs are taken into account.

From a sustainability perspective, both alternatives offer the added benefit of making use of recycled materials and either saving water in production (recycled pavers) or improving the management of water during operation (resin-bound permeable pavers).

Both products are widely available throughout Victoria.

D13.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D13.8 Manufacturers, Alternative Stone Pavers

Recycled Stone	Comments
Allstone	Located in regional Victoria
Various recycling centres	Council landfills or privately run land-fill
Alfred Stone Construction, Artisan	Located in Healesville Victoria
Resin-Bound Pavers	**Comments**
Permapave	Victorian Company
Hydrocon	NSW based company

There is a reasonable market within Victoria for recycled stone blocks and pavers. A number of suppliers were contacted regarding their products and most only supplied 'new' stone pavers and blocks, however, there are a number of speciality suppliers that source and re-sell recycled and reclaimed stone materials.

The long-service life and appearance of recycled stone may have restricted the level of growth in this market. Stronger demand and acceptance of the 'rustic' appearance of recycled stone products might assist growth in this area.

Resin bound pavements and pavers are made through a similar manufacturing process and can be applied to the same applications. The market for resin bound pavements has grown significantly faster than the market for resin bound pavers. This disparity may be due to the manufacturing process associated with this technology, where pavers need to be pre-made but pavements can be mixed and laid on-site.

D14 PAVERS (CONCRETE)

D14.1 General

Concrete pavers are made of a special dry mix pre-cast concrete commonly used in pavement applications. Interlocking pavers are installed over a compacted stone sub-base and a levelling bed of sand. Concrete pavers can be used for many applications. Sand particles are spread over the pavers and tamped down. The sand stabilises the interlocking pavers, yet allows for some flexibility. This type of pavement absorbs stress such as small ground movements (subsidence) and slight ground erosion by flexing. Therefore, they do not easily crack, break or buckle like poured asphalt or concrete.

Key advantages of concrete pavers include:

- Relatively low cost
- Ease of manufacture and variety of shapes, sizes and colours
- Ease of removal, maintenance and repair

Interlocking pavers are manufactured using both fine and coarsely grained aggregate, along with cement compounds. The ingredients are put through pressure and vibration courses, which produce a strong, durable concrete that can then be moulded into various shapes and designs.

Sustainability considerations

As discussed elsewhere in this section, cement and concrete are embedded energy materials. Cement used in concrete production for use in pavement construction was researched, with the research focusing on two alternatives:

- Geopolymer pavers
- Resin bound permeable pavers

Geopolymer pavers

Geopolymers are particularly suitable for paver manufacture. Refer Clause 9.1 for discussion on geopolymers.

The tables below illustrate the sustainability information for Geopolymer pavers.

Table D14.1 Core Indicators, Geopolymer Pavers

Indicator	Information
Embodied Carbon	The embodied carbon in geopolymer cement is approximately 60% lower than OPC
Recycled content	Flyash and slag are the major components of this product; recycled aggregate is also compatible
Cost	The cost of this product is about the same as a standard concrete paver
Geographic/regional/market availability	Available from limited suppliers, but can be sourced within Victoria

Table D14.2 Supplementary Indicators, Geopolymer Pavers

Indicator	Information
Water usage performance	Savings of 30-40% during manufacturing process

Pollutants (other than greenhouse gas):	Sodium silicate used during the process is toxic.
Reusability/Adaptability/Recyclability:	100% recyclable
Practical applicability:	Same strength profile as 100% OPC Increased fire, chemical and salt resistance No training or qualifications are required to lay this type of concrete

Permeable Interlocking Concrete Pavers

Permeable interlocking concrete pavers (PICP) are a sustainable alternative to concrete pavers.

Road surfaces can account for 20-25% of impermeable surfaces which are a major contributor to excess run-off (Concrete Masonry Association of Australia, 2010). PICP assists to achieve reductions in the following areas (Shackel, 2010):

- Rainfall runoff from pavement surfaces
- The size or need for rainwater retention facilities in roadworks by using the pavement itself for retention. This improves land use
- Downstream flooding
- To recharge and maintain aquifers and the natural groundwater
- To trap pollutants that would otherwise contaminate groundwater or drainage systems

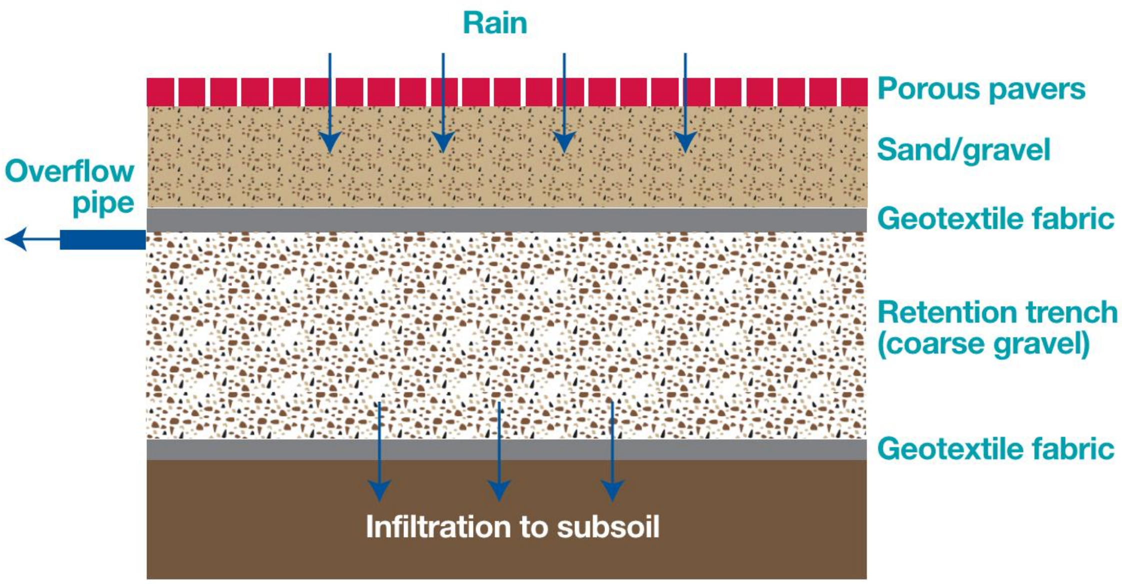
PICP are designed with gaps/spaces between individual interlocking pavers facilitate infiltration. The voids between the pavers are filled with a uniform 2-5 mm aggregate to facilitate rapid infiltration of rainfall (Shackel, 2010). The same aggregate can be used as a bedding material for the pavers.

There are three key levels of infiltration which can be designed with PICP:

1. Full infiltration: all the water infiltrates the subgrade
2. Partial Infiltration: some water infiltrates the subgrade and some water is removed by a discharge pipe
3. No infiltration: water is carried through the paver to assist with drainage, but no water infiltrates the subgrade. All water is removed through a discharge pipe

Figure D14.1 is a cross-section of partial infiltration where a certain amount of overflow is still released into the stormwater system

Figure D14.1 Cross-Section, Permeable/Porous Pavers



(Melbourne Water, Water Sensitive Urban Design Brochure)

In 2006 the Concrete Masonry Association of Australia (CMAA) commissioned the School of Natural and Built Environments at the University of South Australia in conjunction with the author to develop new software called PERMPAVE for permeable pavements and LOCKPAVE for PICP. This software is to aid engineers in the required water management procedures of PICP and permeable pavements (Concrete Masonry Association of Australia 2012)

This product has been used within Europe for the last two decades, and has been on the market in Australia since 1997 (Concrete Masonry Association of Australia, 2010).

The application of this product within Water Sensitive Urban Design (WSUD) is becoming more common. Recent examples of its use in Australia include, Sydney Olympic Park, Smith Street, Manly and Kiama NSW (see **Figure D14.2** and **Figure D14.3**)

Figure D14.2 PICP, Residential Street, Manly

Figure D14.3 PICP, Kiama NSW

(Concrete Masonry Association of Australia 2010)

PICP can be used in a number of ways due to its strong structure and long service-life. Some applications include parking areas, pedestrian areas, low/medium traffic roads and lanes, and leisure spaces.

The tables below illustrate the sustainability information for PICP.

Table D14.3 Core Indicators, PICP

Indicator	Information
Embodied Carbon	There is a reduction of approximately 50% in embodied carbon when using permeable paver instead of a conventional paver.
Recycled content	Blended cement (slag and fly ash) can be used to design the pavers Up to 40% slag and 20% fly ash
Cost	Although the up-front costs of PICP are significantly higher than asphalt or concrete pavers, the whole of life costs are expected to be lower. Factors contributing to this include the reduction or elimination of sub-surface drainage infrastructure
Geographic/regional/market availability	Readily available in regional Victoria

Table D14.4 Supplementary Indicators, PICP

Indicator	Information
Water usage performance	The water performance is dependent on the system selected. For example, a superior system would function as a closed loop and use the water captured in the detention system on or around the site. Other systems may only filter and capture pollutants before discharge to the stormwater system Porous pavements also assist with flood control and run-off
Pollutants (other than greenhouse gas):	Reduction in the amount of pollutants entering the water system Reduction in atmospheric pollutants if blended cement is used
Reusability/Adaptability/Recyclability:	100% recyclable product (as are standard concrete pavers)

<table>
<tr><th>Indicator</th><th>Information</th></tr>
<tr><td>Practical applicability:</td><td>PICP can generally be used in all applications concrete pavers are commonly used:
<table>
<tr><th>Common use for concrete pavers</th><th>PICP suitable?</th><th>Examples</th></tr>
<tr><td>General road paving</td><td>Yes</td><td></td></tr>
<tr><td>High traffic road paving</td><td>No</td><td>n/a</td></tr>
<tr><td>Parking areas and hardstand</td><td>Yes</td><td>Used at Sydney Olympic Park</td></tr>
<tr><td>Footpaths</td><td>Yes</td><td>Used at Sydney Olympic Park</td></tr>
</table>
</td></tr>
</table>

D14.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D14.5 Core indicators, Concrete Pavers

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
Concrete pavers	0	0	5	5
Geopolymer pavers	4	5	4	3
Concrete interlocking pavers	4	3	4	4

Table D14.6 Supplementary indicators, Concrete Pavers

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
Concrete pavers	0	0	-	4
Geopolymer pavers	3	3	-	5
Concrete interlocking pavers	4	3	-	4

The final weighted scores are shown below.

Table D14.7 Weighted scores, Concrete Pavers

Material	Weighted Score (out of 100)
OPC concrete paver	43
Geopolymer paver	80
Concrete interlocking pavers	75

D14.3 Discussion

As with clay and stone pavers, and general concrete mixes, concrete pavers are another item with high embodied carbon due to the energy intensive nature of the extractive and reprocessing activities and transporting requirements.

The two alternatives discussed here, geopolymer cement and permeable interlocking concrete pavers, are both currently available in regional Victoria and suitable for all applications concrete pavers are currently used.

From a sustainability perspective, both alternatives have lower embodied carbon, and make use of recycled materials (recycled materials can be used in the interlocking pavers).

The permeable interlocking concrete pavers have the additional benefit of improving the management of water during operation.

D14.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D14.8 Manufacturers, Alternative Concrete Pavers

Geopolymer Paver	Comments
ZeoBond, ZeoStone Paver	Geopolymer cement cannot be mixed within a standard plant, the whole concrete mix needs to be purchased through this supplier The concrete can be laid by a conventional concrete crew without additional training Melbourne based company and manufacturing plant
Permeable Interlocking Concrete Paver	**Comments**
AdbriMasonary, *EcoPave*, *Ecotrihex*	Available in Victoria This product has been used within Sydney Olympic Park and other major public areas
StoneSet	NSW based company but a plant and registered suppliers are present within Melbourne and regional Victoria, respectively The sales manager stated that where possible recyclable stones and glass are sourced as close to the site as possible with the resin (5% of mix) being imported from NSW There is potential that on-site waste could be used in the mix
Boral, HydraPave	Readily available and mixed within Victoria

The current market for Geopolymer Cement is relatively limited as the product is patented by ZeoBond. However, this product is a Melbourne based company and is available to regional Victoria

Permeable concrete interlocking pavers are available in a number of different styles. The various pavers also can be designed and installed to meet numerous rainfall requirements and sub-base specifications.

Permeable interlocking concrete pavers are becoming very popular for sustainable construction projects (as demonstrated by a number of published case studies, e.g. Sydney Olympic Park) and the growing market reflects this. The market is however, still in its infancy and growing demand may encourage more concrete paver producers to produce this product.

D15 PLASTIC (PIPE)

D15.1 General

PVC is used for a wide variety of applications, the most important of which according to the European Commission are in the building and construction sector (windows/shutters, sheets, flooring and pipes), the electric and electronic equipment sector (predominantly cables), the transport sector (plastisols, artificial leather, dashboards, structural parts) and the packaging sector (non-beverage packaging). PVC consumption has increased by over 60% in the last 40 decades due to its reasonable price, freedom in design, easy processing, various applicability, UV stability, recyclability and relatively low primary energy demand and resource consumption in production[4].

There is some controversy regarding PVC products and their impact on the environment and sustainability, with a widespread belief that PVC is inherently damaging to the environment and to human health. As reported by Edge Environment, studies conducted by LCA internationally, have shown that PVC products are typically no better or worse than the alternatives across a wide range of environmental and health risk assessments. Additionally an earlier study conducted by Edge Environment has shown that the conclusions from international and US work are valid in Australia and that in the case of piping, Australian PVC pipe is typically advantageous environmentally, with copper piping having the biggest environmental impact, followed by Ductile iron pipe. Out of the plastics, the principal findings for pressure pipe are that PVC-o pipe was substantially the best performer, followed by PE and different grades of PVC solid-walled pipe[5].

Sustainability drivers

Although the above research demonstrates that PVC has many beneficial uses and is environmentally superior over other materials such as copper, alternatives can be sourced that are more sustainable and less harmful to the environment.

Research into current and emerging sustainable alternatives, focus on the following materials:

- PVC-O
- Recycled HDPE pipe

PVC-O pipe

PVC-O pipes use the same input material as standard PVC pipes but during the manufacturing process, a controlled stretching process is conducted, after extrusion, which alters the pipe material. The polymer chains are bi-axially orientated in a specific and ordered fashion, allowing the pipe to be expanded in both circumferential and longitudinal directions. This significantly improves the mechanical properties. Subsequently the PVC-O pipes have thinner walls and an increased internal diameter, but can be used at the same pressure rating as the standard PVC pipes (Chasis 2009). According to Vinidex, these environmental and engineering advantages result in a high-performance cost-effective pipe material choice for pressure applications.

[4] Baitz, M et al, 2004, *Life-cycle Assessment of PVC and of Principal Competing Materials*, European Commission.

[5] Howard, N. 2009 *LCA of Australian Pipe*, Edge Environment for PIPA.

The benefits of PVC-O pipes include:

- High flow capacity
- High impact strength
- High toughness
- Excellent damage tolerance
- Light weight
- Corrosion resistant
- No adverse effect on water quality
- Reduced Occupational Health and
- Safety risks
- More Material and energy efficient
- environmentally sustainable

(Vinidex Systems and Solutions, n.d.)

Embodied carbon in PVC-O pipe is slightly higher per kg of finished product; however less of the material is required for every metre of pipe required. When measured over pipe length, the embodied energy in PVC-O pipe is lower than in standard PVC pipe. Reprocessed PVC can also be used to make this product, however most material used is virgin plastic. In addition to the benefit of the manufacturing process, PVC-O material is also 100% recyclable at the end of its service life (Iplex Pipeline n.d.).

The tables below illustrate the sustainability information for PVC-O pipe

Table D15.1 Core Indicators, PVC-O

Indicator	Information
Embodied Carbon	Embodied carbon in PVC-O pipe is slightly higher per kg of finished product, however less of the material is required for every metre of pipe required. When measured over pipe length, the embodied energy in PVC-O pipe is lower than in standard PVC pipe.
Recycled content	Can potentially use reprocessable PVC for its manufacture Most material is virgin plastic
Cost	N/A dependent on required pipe Some suppliers have stated that operational costs would be reduced because of the decreased flow resistance (increased internal diameter) and subsequent lower pumping costs. The pipe also has an improved corrosion resistance (longer-life and no corrosion protection required)
Geographic/regional/market availability	Available in regional Victoria from local suppliers Current suppliers to the IDM Group supply this product

Table D15.2 Supplementary Indicators, PVC-O

Indicator	Information
Water usage performance	Improved flow capacity due to thinner walls (larger internal diameter) and smoother surfacing (71.25 kL/t of water saved)
Pollutants (other than greenhouse gas):	Information not available. (Pollutants producing PVC are not available?)
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Wide application wherever PVC pipes are currently used

Recycled HDPE Pipe

Recycled HDPE Pipes are made from 100% recycled plastic bottles and are now widely used for civil, agricultural and forestry applications. Recycled HDPE pipes are generated through various types of readily available plastics. It is unusual to obtain recycled PVC pipes as the lifespan for plastic pipes is about 100 years, hence the amount of pipes entering the waste stream is very low (Department of Sustainability, Environment, Water, Population and Communities 2012).

This product has been tested, rated and approved by VicRoads (2009) for use under public roads in Victoria, and is certified to AS/NZS 1462.22:1997 and AS/NZS 2566.1:1998

Embodied carbon in recycled HDPE pipes is 90% lower than in virgin PVC piping. Additionally construction materials are readily available and 100% recyclable. These pipes are 25% cheaper to produce than PVC pipes and readily available. As with the PVC-O pipes, this product can be used in all applications that PVC pipes are used.

The tables below illustrate the sustainability information for recycled HDPE pipe

Table D15.3 Core Indicators, HDPE Pipe

Indicator	Information
Embodied Carbon	Embodied carbon in recycled HDPE is 90% lower than in virgin PVC piping.
Recycled content	100% recycled content HDPE obtained from recycling plastic bottles is a readily available feedstock
Cost	The fully installed/life-cycle cost is lower than competitors The product is 25% cheaper to produce than PVC pipes
Geographic/regional/ market availability	Current supplier for some Councils within the IDM Group Readily available

Table D15.4 Supplementary Indicators, HDPE Pipe

Indicator	Information
Water usage performance	N/A
Pollutants (other than greenhouse gas):	N/A
Reusability/Adaptability/ Recyclability:	100% recyclable
Practical applicability:	Recycled HDPE pipes can generally be used in all applications that PVC pipes are used.

D15.2 Findings

The following tables present the rating of each product against the core indicators and relevant supplementary indicators.

Table D15.5 Core indicators, Plastic Pipe

Product	Carbon	Recycled content	Cost	Geographic/regional/market availability
PVC	0	0	4	5
PVC-O	4	5	5	4
Recycled HDPE	2	2	5	4

Table D15.6 Supplementary indicators, Plastic Pipe

Product	Water usage performance	Pollutants (other than greenhouse gas)	Reusability/Adaptability/Recyclability	Practical applicability
PVC	0	0	-	-
PVC-O	4	4	-	-
Recycled HDPE	3	0	-	-

The final weighted scores are shown below.

Table D15.7 Weighted scores, Plastic Pipe

Material	Weighted Score (out of 100)
PVC Pipe	36
PVC-O Pipe	58
Recycled HDPE	88

D15.3 Discussion

Whilst traditional PVC piping only has moderately high embodied carbon, additional issues, such as the lack of recycled content, the high water use in production, and the toxicity of some of the ingredients, mean that there is an opportunity to consider more sustainable alternatives.

The two alternatives discussed here, PVC-O pipe and recycled HDPE pipe, are both currently available in regional Victoria and suitable for most applications PVC pipe is currently used. They are both also comparable (and cheaper) in cost.

From a sustainability perspective, both alternatives have lower embodied carbon. The recycled HDPE pipe also makes use of recycled materials.

D15.4 Market assessment

The following is a select list of manufacturers and, where relevant, their brand of material (in italics) along with comments about supply.

Table D15.8 Manufacturers, Alternative Plastic Pipe

PVC-O Pipe	Comments
Iplex, ApolloBLUE	Regional supplier in Victoria, current IDM supplier
Vinidex, Supermain PVC-O	Regional supplier in Victoria, current IDM supplier
HDPE Pipe	**Comments**
The Green Pipe	Regional supplier in Victoria, current IDM supplier Manufactured in Laverton, Victoria and southern NSW

The Green Pipe, although a patented product, has a very strong market within Victoria. This product is well established and has been used within a number of government funded major infrastructure projects throughout Australia. This is also a current supplier to some Councils within the IDM Group.

PVC-O pipes have improved performance compared to the standard PVC pipe and are manufactured through an alternative process. The stock material for both of the PVC pipe is the same, and therefore, manufacturers of PVC could begin manufacturing PVC-O pipes.

Demand will drive the market to evolve and include PVC-O pipes into their products lists. This may not be the case for small companies as it is anticipated updated machinery and technologies would be required. Nonetheless, distribution of the alternative product should be encouraged within local stores and warehouses.