UDIA WA and Industry Partners

Land Development Infrastructure

Life Cycle Assessment Study

Date: 25 July 2023

Cerclos

Contents

1 Introduction

Managing the environmental impacts that arise from the construction and operation of buildings and infrastructure is of key importance in mitigating the damage caused directly and indirectly on the biosphere. Life Cycle Assessment (LCA) is the leading industry standard in clearly identifying optimum strategies for reducing environmental impacts. This report presents the results of the infrastructure LCA studies of 115 Hamilton Hill, Orion Industrial Park, and Bushmead land developments.

The studies have been conducted using eTool accordance with the following standards:

- International Standards ISO 14040 and 14044.
- European Standard EN 15978: Sustainability of Construction Works – Assessment of Environmental Performance of Buildings – Calculation Method

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2 Project Descriptions

2.1 OneOneFive Hamilton Hill (Development WA)

OneOneFive Hamilton Hill is a new residential estate being developed on the former Hamilton Senior High School site, south of Perth.

The new estate will feature approximately 232 lots and offer a diverse range of new housing options, including single residential home sites, townhouses, and compact lots along with four grouped housing sites.

As one of Development WA's Innovation Through Demonstration projects, OneOneFive Hamilton Hill targets the highest levels of sustainability and is delivering an ecologically sensitive development – minimising water and energy consumption, while retaining the site's landform, trees, and biodiversity.

The estate has been recognised by Water Corporation as a Waterwise Platinum development, the Urban Development Institute of Australia awarding the maximum 6 leaves for their EnviroDevelopment program and was also a winner at the 2021 Waste Sorted Awards.

2.2 Bushmead Land Development (Cedar Woods)

Bushmead is designed as an environmentally sustainable community located just 16km from the Perth CBD. Set amongst 185 hectares of retained bush with stunning Perth city views, the residential lots at Bushmead take advantage of the area's natural beauty.

Sustainability has been a key part of the design philosophy for Bushmead and the development has been awarded 5-Leaf EnviroDevelopment accreditation. It has also been recognised with excellence awards from UDIA, an award for parks and open space from the Australian Institute of Landscape Architects (AILA), and a Waterwise Development award from the Water Corporation.

2.3 Orion Industrial Park (Development WA)

Orion Industrial Park is transforming 95ha of former limestone quarries into a new industrial area aimed at servicing a range of industries. The estate, when complete, will house up to 50 businesses.

Positioned next to the Australian Marine Complex and midway between Fremantle and the proposed Kwinana land-backed outer harbour wharf, Orion Industrial Park is positioned to offer advantages to businesses in the freight, logistics, warehousing, fabrication, and engineering industries.

3 Goal of the Study

This study aims to profile and understand the environmental performance of the infrastructure works for the three land developments. The life cycle performance of the projects is compared to models representing business-as-usual practices and as such this is a comparative study. The study has been conducted on the assumption the results may be made public.

A further goal of these studies is to develop a framework for assessing and reporting the life cycle environmental impacts of urban land developments.

4 Scope of the Study

The LCA study has been conducted in accordance with the EN 15978 standard to assess the direct and indirect potential environmental impacts associated with the infrastructure construction works associated with the three land developments.

4.1 Functional Unit

The project's function must reflect the asset's core purpose so that it can be compared accurately to different designs. In this case, the functional focus is the Whole Development, and the chosen functional unit is the impact per lot over its life span.

It is important to note that impact per lot is not necessarily the most appropriate functional unit in all cases. It is also important to note that comparisons between different types of land development i.e., residential, commercial, industrial, etc., are not appropriate.

For residential land developments, we recommend using yield i.e., the number of dwellings as the functional unit. A functional unit of yield will allow comparison between developments regardless of whether they are large, small, high-density, low-density, green-field or brown-field.

More work is needed to determine the ideal functional unit for industrial and commercial developments.

The modelled design life for the developments is 100 years which has been adopted for the LCA study period. Note that the development is not expected to be removed or demolished after 100 years; this timeframe has simply been selected as the study period horizon.

Note that products with expected service lives of less than the LCA study period of the project are assumed to be replaced at increments reflecting their service life.

4.2 System Boundary

The system boundary, shown in Figure 1, follows the guidance given in EN 15978.

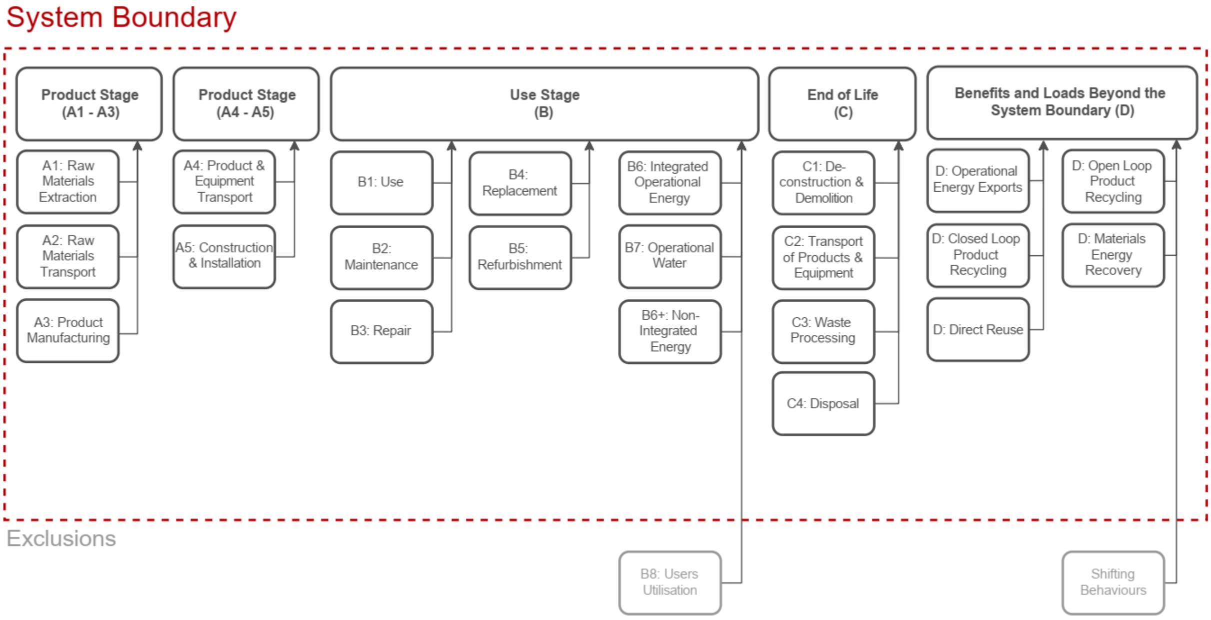

Figure 1: System Boundary Diagram

4.3 Environmental Indicators

The environmental indicators that have been included in the study are detailed in Table 1. For further information regarding the environmental indicators, refer to Appendix A.

Table 1: Environmental Indicators Included in LCA Study

Environmental Indicator	Unit	Abbreviation	Characterisation Method
Environmental Impacts			
Global Warming Potential, GWP	kg CO_2 eq	GWP	CML-IA baseline V4.5
Ozone Depletion Potential, ODP	kg CFC-11 eq	ODP	CML-IA baseline V4.5
Acidification Potential for Soil and Water, AP	kg SO_2 eq.	AP	CML-IA baseline V4.5
Eutrophication potential, EP	kg PO_4 eq	EP	CML-IA baseline V4.5
Photochemical Ozone Creation Potential, POCP	kg ethylene	POCP	Institute of Environmental Sciences (CML)
Abiotic Depletion Potential – Elements, ADPE	kg antimony	ADPE	CML-IA baseline V4.5
Abiotic Depletion Potential – Fossil Fuels, ADPF	MJ	ADPF	CML-IA baseline V4.5

5 Cut-off Criteria

The EN 15978 cut-off criteria were used to ensure that all relevant potential environmental impacts were appropriately represented:

- Mass – if a flow is less than 1% of the mass at either a product-level or individual-process level, then it has been excluded, provided its environmental relevance is not of concern.

- Energy – if a flow is less than 1% of the energy at either a product-level or individual-process level, then it has been excluded, provided its environmental relevance is not a concern.
- The total of neglected input flows per module, e.g. per module A1-A3, A4-A5, B1-B5, B6-B7, C1-C4 and module D shall be a maximum of 5% of energy usage and mass.
- Environmental relevance – if a flow meets the above criteria for exclusion, but is considered to potentially have a significant environmental impact, it has been included. All material flows which leave the system (emissions) and whose environmental impact is higher than 1% of an impact category have been included.

The Operational Guidance for Life Cycle Assessment Studies (Wittstock et al. 2012) states:

The apparent paradox is that one must know the final result of the LCA (so one can show that the omission of a certain process is insignificant for the overall results) to be able to know which processes, elementary flows, etc. can be left out.

The approach taken in this study is to continue modelling smaller inputs until confidence is gained that the criteria are safely met.

6 Allocation

Allocation rules follow those of EN 15804 as given below:

- Allocation will respect the main purpose of the studied processes. If the main purpose of combined processes cannot be defined (e.g. combined mining and extraction of nickel and precious metals), economic allocation may be used to divide resources and emissions between the products.
- The principle of modularity is maintained. Where processes influence the product's environmental performance during its life cycle, they will be assigned to the module where they occur.
- The sum of the allocated inputs and outputs of a unit process is equal to the inputs and outputs of the unit process before allocation. This means no double counting of inputs or outputs is permissible.

7 Results

7.1 OneOneFive Hamilton Hill (Development WA)

7.1.1. Life Cycle Impacts

The results of the OneOneFive Hamilton Hill life cycle study are shown in Table 2 below. Within the table are the impacts across the 7 assessed environmental indicators, including Global Warming Potential (GWP - carbon impact) across the EN 15978 life cycle modules (refer to 4.2 System Boundary for an explanation of the EN 15978 modules). Red highlighted text indicates the highest impact module for each indicator, and orange highlighted text indicates the second highest impact module.

Table 2: Environmental Impacts of Each Life Cycle Phase

Characterised Impacts Per Absolute(No Functional Unit) Per No Time Scale		Construction Phases			Use Phases								End of Life Phases				Benefits and Loads Beyond the System Boundary	Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B6+	B7	C1	C2	C3	C4	D	
Proposed Design																		
GWP	kg CO_2 eq	1.2E+6	7.2E+5	1.7E+6	-3.0E+1	3.7E+5	0.0E0	1.2E+6	0.0E0	5.4E+5	0.0E0	-1.0E-11	0.0E0	3.6E+5	0.0E0	1.3E+5	-1.8E+5	6.1E+6
ODP	kg CFC-11 eq	4.2E-2	8.2E-2	2.5E-1	0.0E0	5.6E-2	0.0E0	8.3E-2	0.0E0	1.0E-3	0.0E0	1.3E-19	0.0E0	4.0E-2	0.0E0	3.2E-2	-4.1E-3	5.8E-1
AP	kg SO_2 eq.	9.5E+3	3.0E+3	4.9E+3	0.0E0	2.3E+3	0.0E0	1.1E+4	0.0E0	9.0E+2	0.0E0	2.9E-14	0.0E0	1.6E+3	0.0E0	7.5E+2	-3.2E+3	3.1E+4
EP	kg PO_4 eq	8.2E+3	8.1E+2	1.0E+3	0.0E0	4.9E+2	0.0E0	8.8E+3	0.0E0	3.0E+2	0.0E0	3.6E-15	0.0E0	4.1E+2	0.0E0	1.7E+2	-3.6E+3	1.7E+4
POCP	kg ethylene	4.3E+2	2.9E+2	3.2E+2	0.0E0	2.1E+2	0.0E0	6.4E+2	0.0E0	2.2E+1	0.0E0	-1.6E-16	0.0E0	9.7E+1	0.0E0	2.9E+1	-1.6E+2	1.9E+3
ADPE	kg antimony	2.3E+2	7.1E+1	1.1E+1	0.0E0	6.0E+1	0.0E0	4.0E+2	0.0E0	2.5E+1	0.0E0	-1.6E-16	0.0E0	4.5E+1	0.0E0	5.1E0	-9.7E+1	7.5E+2
ADPF	MJ	1.4E+7	1.1E+7	2.5E+7	0.0E0	7.9E+6	0.0E0	1.7E+7	0.0E0	7.0E+6	0.0E0	-2.4E-10	0.0E0	5.7E+6	0.0E0	3.1E+6	-2.0E+6	8.9E+7

7.1.2. Environmental Strategy Performance

Figure 2 is a waterfall chart of carbon savings resulting from the 10 environmental strategies included in the proposed design of OneOneFive Hamilton Hill compared to business as usual. Of the strategies, **Site Sourced Aggregates, Sand** resulted in the highest saving, followed by **Water Efficient Irrigation**. Overall, the 10 strategies reduced the life cycle carbon impact of the project by 12.1%.

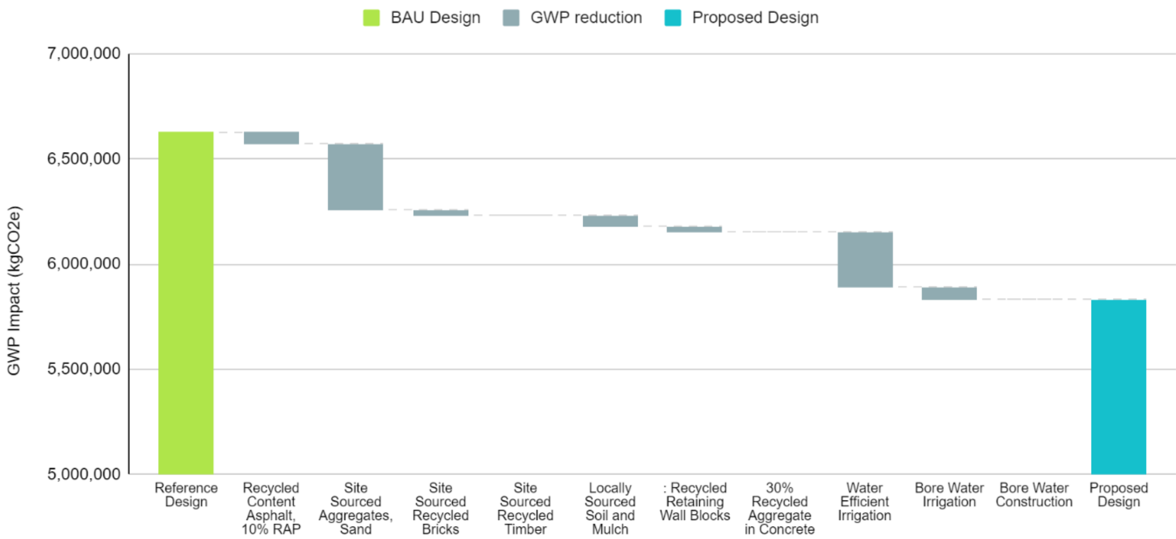

Figure 2: OneOneFive Hamilton Hill Carbon Saving Strategies

7.1.3. Detailed Analysis

A breakdown of the highest impact materials in the study is shown in Figure 3, and a breakdown of the impacts by life cycle stage is shown in Figure 4.

The highest contributing single material to the life cycle GWP impact is concrete ('Concrete | Unreinforced | Portland Cement Blends') and the second highest contributing material is recycled concrete aggregate ('Bulk Aggregates | Recycled Building Rubble (Compacted)'), followed by recycled limestone blocks, steel products ('Ferrous Metals | Steel | Galvanised Structural | Unspecified'), and Portland cement-based mortar ('Cementitious Binders | Portland Cement'). Overall, the top 5 impact materials make up 64% of material impacts.

Construction (module A5) is the largest contributing life cycle stage at 29.1% of the overall life cycle GWP impact. This is the construction effort, i.e., the impact of the construction equipment itself. Recurring impacts throughout the operational phase of the life cycle (modules B2-B4) represent 24% of the life cycle GWP impact. This includes maintenance of landscaped areas, roads, paved areas, and services. Products (materials, module A1-A3) and transport (module A4) represent 17% and 10.8% of life cycle GWP impact respectively.

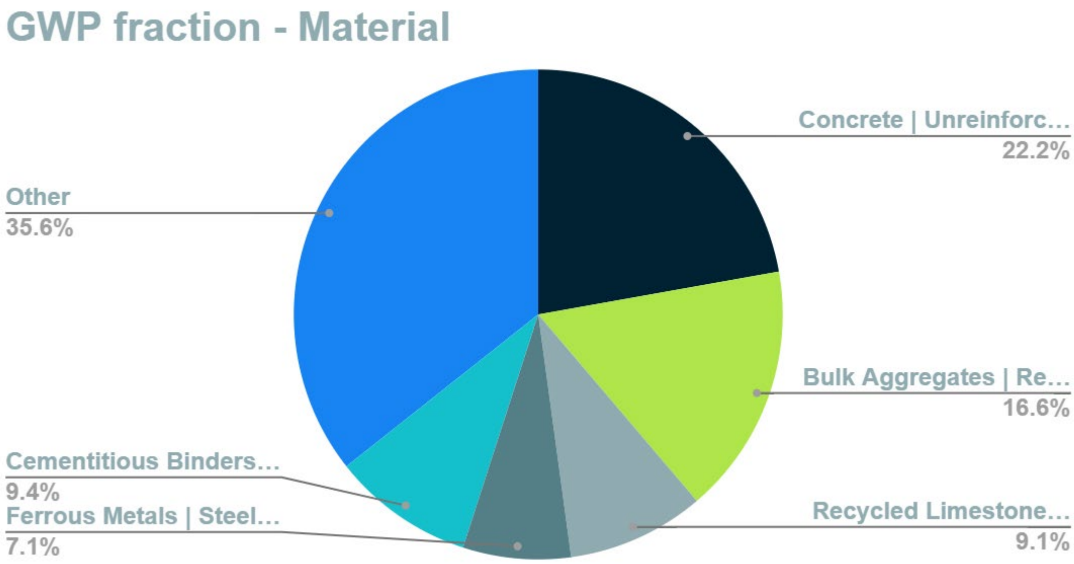

Figure 3: Top 5 Materials by GWP Impact

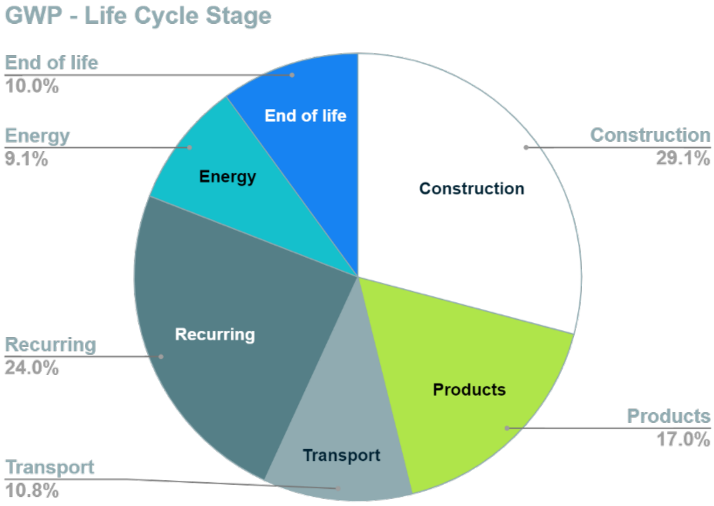

Figure 4: GWP Impacts per life cycle stage

Understandably both the top materials and the construction categories are made up of many individual items (there are over 700 individual items in the LCA model). Table 3 shows the top 10 contributing individual items to the overall GWP impact along with the life cycle module in which they are occurring.

Three of the top ten individual items (indeed three of the top five) are construction equipment, predominantly used to move bulk fill across the site. Notably, the operational energy of street lighting is the second largest contributing individual item. Together with Figures 3 & Figure 4, these items provide some guidance on which items could be targeted to further reduce the carbon impact of this project or future projects.

Table 3: OneOneFive Hamilton Hill - Top 10 individual items contributing to GWP Impact

Rank	Element	Module	GWP Impact (kgCO2e)	
1	Construction Equipment – Loader	A5	683,877.40	
2	Operational Energy - Street Lighting	B6	541,265.33	
3	Construction Equipment - Loader	A5	503,963.03	
4	Construction Equipment - Dump Truck	A5	341,812.62	
5	Cementitious Binders | Portland Cement | Unspecified	A1A3	174,613.33	
6	Trade Staff (No Equipment, labour transport only), Electricity	B4	172,645.64	
7	Plant-Based Products (non-Timber) | Mulch | Bark	B2B3	172,615.85	
8	Bulk Aggregates | Recycled Building Rubble (Compacted)	C2	162,411.98	
9	Highway 4 x 6 Dump Truck, Diesel	A4	134,238.02	
10	Recycled Limestone Blocks	C2	117,709.38	

7.2 Bushmead Land Development (Cedar Woods)

7.2.1. Life Cycle Impacts

The results of the Bushmead life cycle study are shown in Table 4 below. Within the table are the impacts across the 7 assessed environmental indicators, including Global Warming Potential (GWP – carbon impact) across the EN 15978 life cycle modules (refer to 4.2 System Boundary for an explanation of the EN 15978 modules). Red highlighted text indicates the highest impact module for each indicator, and orange highlighted text indicates the second highest impact module.

Table 4: Environmental Impacts of Each Life Cycle Phase

Characterised Impacts Per Absolute(No Functional Unit) Per No Time Scale		Construction Phases			Use Phases								End of Life Phases				Benefits and Loads Beyond the System Boundary	Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B6+	B7	C1	C2	C3	C4	D	
Proposed Design																		
GWP	kg CO_2 eq	4.3E+7	4.2E+7	5.9E+7	0.0E0	2.9E+6	0.0E0	2.4E+7	0.0E0	6.9E+6	0.0E0	0.0E0	0.0E0	3.0E+6	0.0E0	1.6E+6	-2.0E+6	1.8E+8
ODP	kg CFC-11 eq	2.1E0	5.0E0	8.5E0	0.0E0	4.2E-1	0.0E0	1.6E0	0.0E0	1.3E-2	0.0E0	0.0E0	0.0E0	3.3E-1	0.0E0	2.8E-1	-4.3E-2	1.8E+1
AP	kg SO_2 eq.	2.0E+5	1.7E+5	1.6E+5	0.0E0	1.1E+4	0.0E0	1.5E+5	0.0E0	1.1E+4	0.0E0	0.0E0	0.0E0	1.3E+4	0.0E0	8.5E+3	-3.3E+4	6.9E+5
EP	kg PO_4 eq	1.0E+5	4.4E+4	3.3E+4	0.0E0	2.4E+3	0.0E0	9.1E+4	0.0E0	3.9E+3	0.0E0	0.0E0	0.0E0	3.3E+3	0.0E0	3.4E+3	-3.5E+4	2.5E+5
POCP	kg ethylene	8.6E+3	1.3E+4	1.1E+4	0.0E0	7.2E+2	0.0E0	7.2E+3	0.0E0	2.8E+2	0.0E0	0.0E0	0.0E0	7.9E+2	0.0E0	3.3E+2	-1.7E+3	4.0E+4
ADPE	kg antimony	4.7E+3	4.6E+3	2.0E+2	0.0E0	4.7E+2	0.0E0	4.0E+3	0.0E0	3.1E+2	0.0E0	0.0E0	0.0E0	3.7E+2	0.0E0	7.2E+1	-1.2E+3	1.4E+4
ADPF	MJ	5.9E+8	6.7E+8	8.3E+8	0.0E0	7.0E+7	0.0E0	3.6E+8	0.0E0	8.9E+7	0.0E0	0.0E0	0.0E0	4.7E+7	0.0E0	3.1E+7	-2.2E+7	2.7E+9

7.2.2. Environmental Strategy Performance

Figure 5 is a waterfall chart of carbon savings resulting from the 3 environmental strategies included in the proposed design of the Bushmead development compared to business as usual. Of the strategies, the **100% Recycled Road Base Course** resulted in the highest saving. Although the carbon reduction from these strategies was not significant, savings from retaining large areas of natural bushland, and minimising new landscaped areas were not able to be quantified in this study. These strategies are expected to have a significant benefit for biodiversity and could also save significant quantities of carbon.

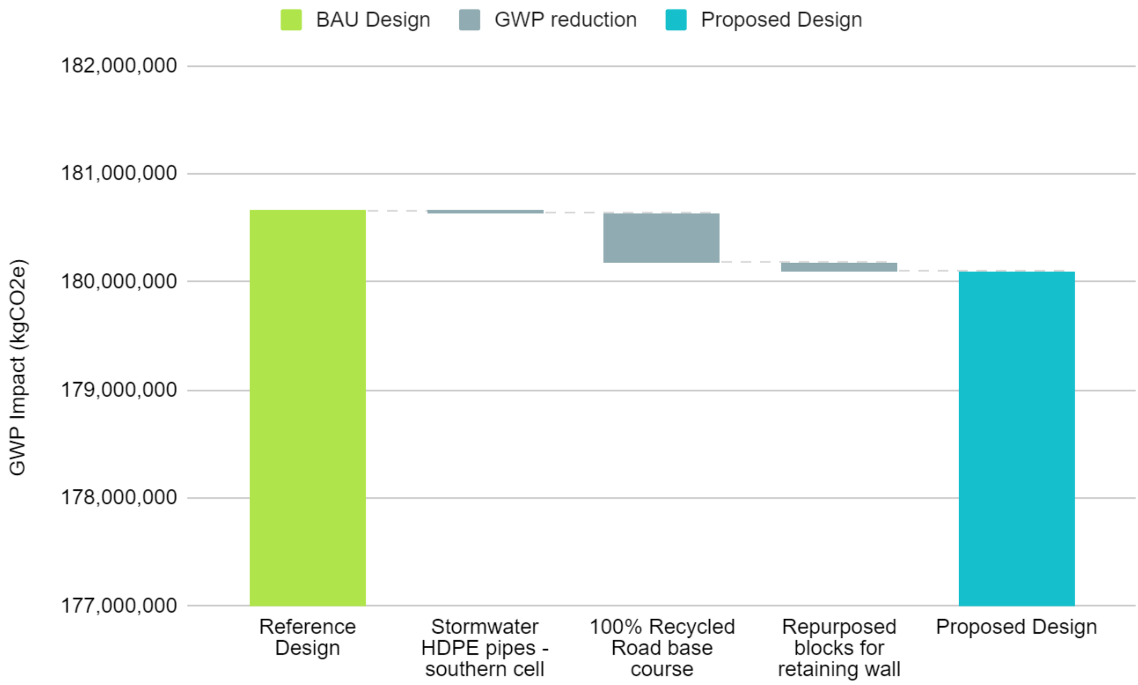

Figure 5: Bushmead Development Carbon Saving Strategies

7.2.3. Detailed Analysis

A breakdown of the highest impact materials in the study is shown in Figure 6, and a breakdown of the impacts by life cycle stage is shown in Figure 7.

The highest contributing single material to the life cycle GWP impact is bulk fill (sand) and the second highest contributing material is stone (for retaining and paving), followed by concrete, bulk fill (soil), and bulk aggregate (gravel). Overall, the top 5 impact materials make up 68% of material impacts.

Construction (module A5) is the largest contributing life cycle stage at 32.2% of the overall life cycle GWP impact. This is the construction effort, i.e., the impact of the construction equipment itself. Products (materials, module A1-A3) represent 23.6% of the life cycle GWP impact (details in Figure 6). Transport (module A4), and recurring impacts throughout the operational phase of the life cycle (modules B2-B4) represent 22.8% and 15% of life cycle GWP impact respectively.

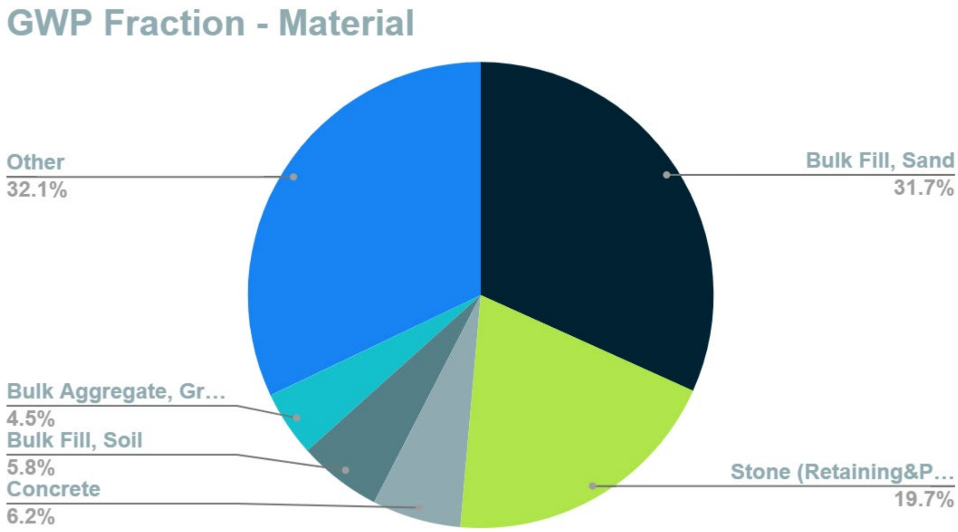

Figure 6: Top 5 Materials by GWP Impact

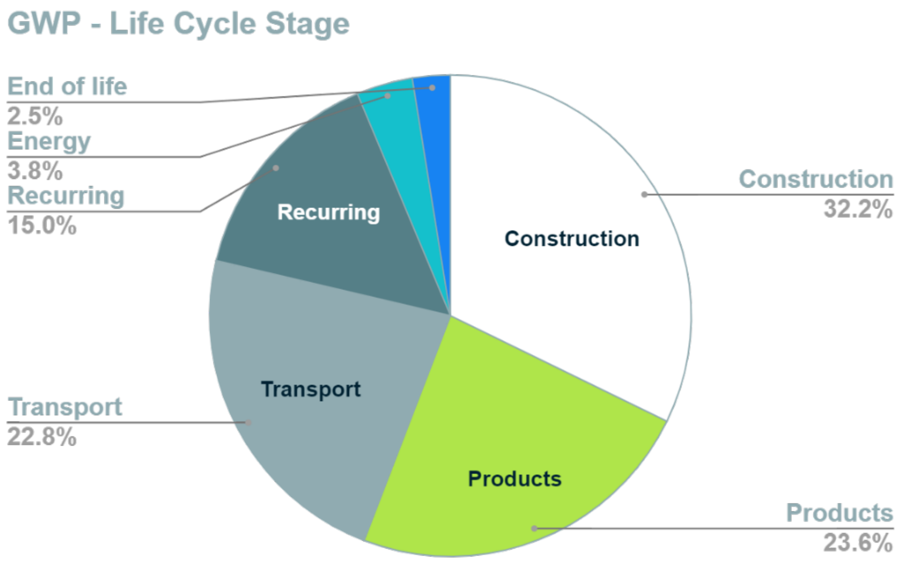

Figure 7: GWP Impacts per life cycle stage

As with OneOneFive Hamilton Hill, both the top materials and the construction categories are made up of many individual items. Table 5 shows the top 10 contributing individual items to the overall GWP impact along with the life cycle module in which they are occurring.

Similarly, to OneOneFive Hamilton Hill, four of the top ten individual items are construction equipment, predominantly used to move bulk fill across the site. Transport of bulk fill is also a large contributor at number 2 and number 10. The operational energy of the street lighting is again present in the top ten items. Together with Figures 6 & Figure 7, these items provide some guidance on which items could be targeted to further reduce the carbon impact of this project or future projects.

Table 5: Bushmead – Top 10 individual items contributing to GWP Impact

Rank	Element	Module	GWP Impact (kgCO2e)	
1	Construction Equipment – Compactor	A5	34,353,477.82	
2	Transport of Bulk Fill – Sand	A4	20,771,504.89	
3	Material – Stone (Retaining & Paving)	A1A3	12,628,710.73	
4	Construction Equipment – Loader	A5	10,227,727.84	
5	Material – Bulk Fill, Sand	A1A3	8,144,543.43	
6	Construction Equipment – Loader	A5	6,924,270.32	
7	Operational Energy – Street Lighting	B6	6,894,860.49	
8	Repair/Replacement – Stone (Retaining & Paving)	B4	6,331,517.12	
9	Construction Equipment – Dump Truck	A5	5,431,333.24	
10	Transport of Bulk Fill – Soil	A4	4,576,308.17	

7.3 Orion Industrial Park (Development WA)

7.3.1. Life Cycle Impacts

The results of the Orion Industrial Park life cycle study are shown in Table 6 below. Within the table are the impacts across the 7 assessed environmental indicators, including Global Warming Potential (GWP – carbon impact) across the EN 15978 life cycle modules (refer to 4.2 System Boundary for explanation of the EN 15978 modules). Red highlighted text indicates the highest impact module for each indicator, and orange highlighted text indicates the second highest impact module.

Table 6: Environmental Impacts of Each Life Cycle Phase

Characterised Impacts Per Absolute(No Functional Unit) Per No Time Scale		Construction Phases			Use Phases								End of Life Phases				Benefits and Loads Beyond the System Boundary	Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B6+	B7	C1	C2	C3	C4	D	
Proposed Design																		
GWP	kg CO_2 eq	3.3E+6	3.1E+6	6.2E+6	0.0E0	1.0E+6	0.0E0	5.1E+6	0.0E0	1.9E+6	0.0E0	5.4E+5	0.0E0	1.1E+6	0.0E0	3.9E+4	-6.2E+5	2.2E+7
ODP	kg CFC-11 eq	2.1E-1	3.7E-1	8.9E-1	0.0E0	2.1E-1	0.0E0	4.4E-1	0.0E0	3.7E-3	0.0E0	5.0E-3	0.0E0	1.2E-1	0.0E0	3.6E-3	-1.6E-2	2.2E0
AP	kg SO_2 eq.	3.6E+4	1.3E+4	1.7E+4	0.0E0	4.5E+3	0.0E0	4.5E+4	0.0E0	3.2E+3	0.0E0	9.9E+2	0.0E0	4.6E+3	0.0E0	8.6E+1	-1.4E+4	1.1E+5
EP	kg PO_4 eq	3.5E+4	3.4E+3	3.6E+3	0.0E0	9.5E+2	0.0E0	3.7E+4	0.0E0	1.1E+3	0.0E0	3.3E+2	0.0E0	1.2E+3	0.0E0	2.0E+1	-1.6E+4	6.7E+4
POCP	kg ethylene	1.6E+3	1.2E+3	1.1E+3	0.0E0	2.8E+2	0.0E0	2.3E+3	0.0E0	7.8E+1	0.0E0	3.7E+1	0.0E0	2.8E+2	0.0E0	7.9E0	-6.1E+2	6.3E+3
ADPE	kg antimony	6.4E+2	3.0E+2	3.3E+1	0.0E0	9.2E+1	0.0E0	9.4E+2	0.0E0	8.7E+1	0.0E0	2.4E+1	0.0E0	1.3E+2	0.0E0	5.9E-1	-3.2E+2	1.9E+3
ADPF	MJ	5.5E+7	4.9E+7	8.8E+7	0.0E0	3.1E+7	0.0E0	8.7E+7	0.0E0	2.5E+7	0.0E0	6.9E+6	0.0E0	1.7E+7	0.0E0	3.6E+5	-6.8E+6	3.5E+8

7.3.2. Environmental Strategy Performance

Figure 8 is a waterfall chart of carbon savings resulting from the 5 environmental strategies included in the proposed design of the Orion Industrial Park compared to business as usual. Of the strategies, **Recycled and locally sourced Aggregate** resulted in the highest saving, followed by **Locally sourced Limestone for Sub-base**. Overall, the 5 strategies reduced the life cycle carbon impact of the project by just under 4%.

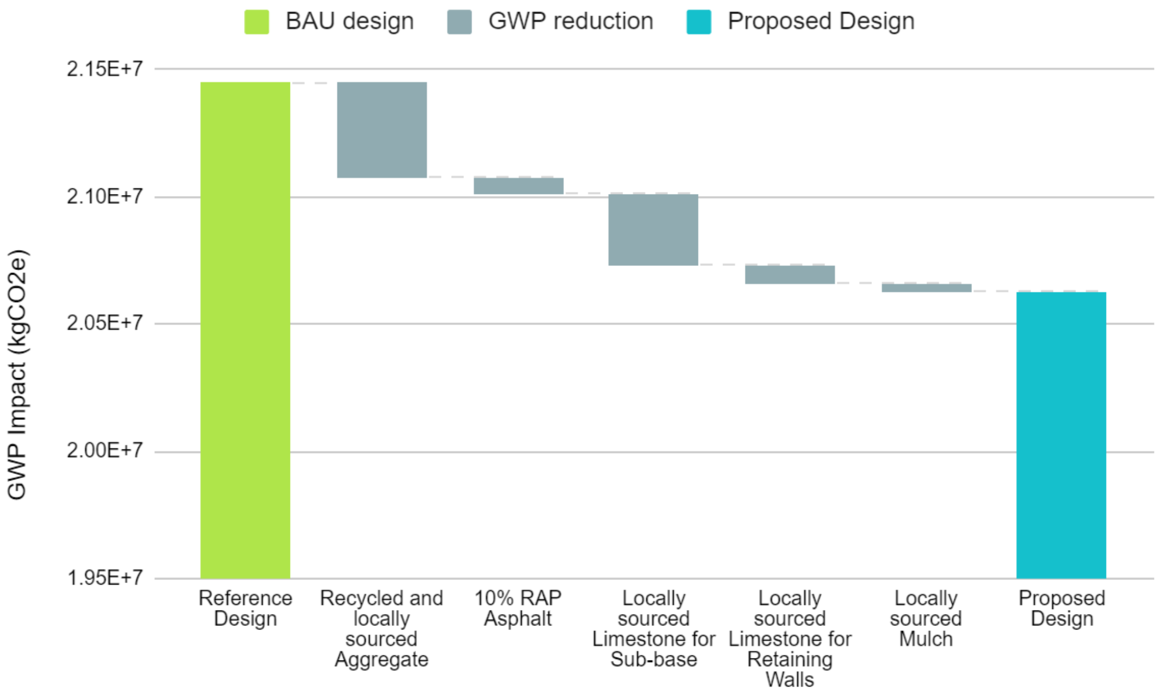

Figure 8: Orion Industrial Park Carbon Saving Strategies

7.3.3. Detailed Analysis

A breakdown of the highest impact materials in the study is shown in Figure 9, and a breakdown of the impacts by life cycle stage is shown in Figure 10.

The highest contributing single material to the life cycle GWP impact is asphalt (10% RAP) and the second highest contributing material is limestone (used as road sub-base and for retaining walls), followed by aggregates for road base, concrete, and plastics (for drainage and other pipework). Overall, the top 5 impact materials make up 58% of material impacts.

Construction (module A5) is the largest contributing life cycle stage at 27.9% of the overall life cycle GWP impact. This is the construction effort, i.e., the impact of the construction equipment itself. Recurring impacts throughout the operational phase of the life cycle (modules B2-B4) represent 27.4% of the life cycle GWP impact. This includes maintenance of roads, paved areas, and services. Products (materials, module A1-A3) and transport (module A4) represent 14.9% and 13.7% of life cycle GWP impact respectively.

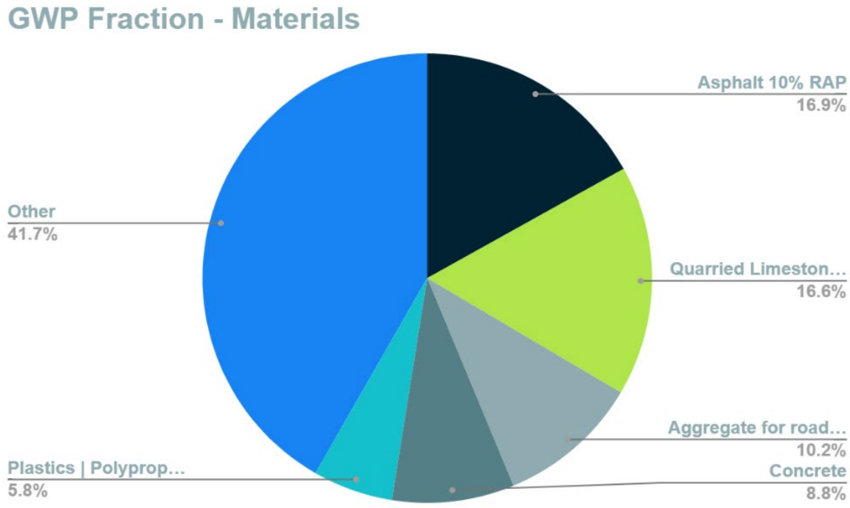

Figure 9: Top 5 Materials as per their GWP Impacts

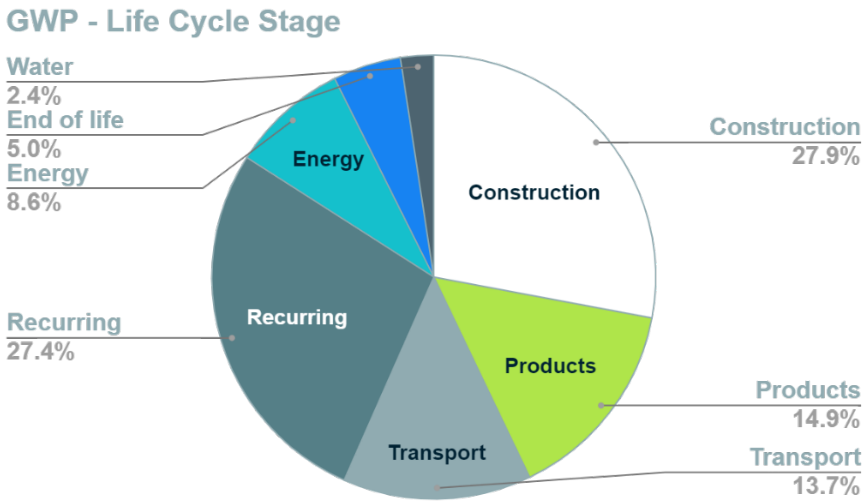

Figure 10: GWP impacts per life cycle stage

As with the other studies both the top materials and the construction categories are made up of many individual items. Table 7 shows the top 10 contributing individual items to the overall GWP impact along with the life cycle module in which they are occurring.

Similarly, to the other projects, four of the top ten individual items (indeed four of the top five in this case) are construction equipment, and again predominantly for moving bulk fill across the site. Operational energy of the street lighting is again present, this time as the top individual item. Also featured are two items related to road maintenance. Compared to residential developments, it seems reasonable to conclude that industrial developments will have greater demand for road maintenance due to the different nature of the traffic. Together with Figure 9 & Figure 10, these items provide some guidance on which items could be targeted to further reduce the carbon impact of this project or future projects.

Table 7: Orion Industrial Park – Top 10 individual items contributing to GWP Impact

Rank	Element	Module	GWP Impact (kgCO2e)
1	Operational Energy – Street Lighting	B6	1,912,383.44
2	Construction Equipment – Compactor	A5	1,871,874.86
3	Construction Equipment – Dump Truck	A5	1,431,758.06
4	Construction Equipment – Loader	A5	1,066,405.56
5	Construction Equipment – Loader	A5	753,647.07
6	Transport of Bulk Fill from Stage 2	A4	704,140.22
7	Material Maintenance – Asphalt (10% RAP)	B2B3	702,369.80
8	Material Maintenance – Bulk Aggregates (Gravel)	B4	618,349.53
9	End of Life Disposal of Bulk Aggregates (Gravel)	C2	610,534.18
10	Operational Water – Irrigation	B7	538,634.40

8 Discussion

8.1 Constraints

Due to variances in the availability of documents for the three developments, achieving a consistent scope of assessment was one of the challenges encountered with the project. There was ultimately some difference, as highlighted in Tables 8 and 9. It is worth noting that soft landscaping was not in scope for the Bushmead development, however, this development has been very deliberate in minimising landscaped areas. This reduces the need for irrigation – which was found to be significant for Orion Industrial Park, and for the application and maintenance of mulch – which was found to be significant for OneOneFive Hamilton Hill.

Due to the significance of soft landscaping to life cycle carbon – as found for both Orion Industrial Park, and OneOneFive Hamilton Hill – it is recommended that soft landscaping be included in scope wherever possible.

Table 8: Structural scope of LCI collection comparison between developments

Key: ✓ In Scope ✓ Partial ✗ Out of Scope

Category Name	Hamilton Hill	Bushmead	Orion Industrial
Substructure	✓ (Partial)	✓ (Partial)	✓ (Partial)
Superstructure	✓ (Partial)	✓ (Partial)	✓ (Partial)
Internal finishes	✓ (Partial)	✗	✗
Fittings, furnishings and equipment	✓ (Partial)	✓ (Partial)	✓ (Partial)
Services equipment	✓ (Partial)	✓ (Partial)	✓ (Partial)
Prefabricated buildings and building units	✗	✗	✗
Work to existing building	✗	✗	✗
External works	✓	✓ (Partial)	✓ (Partial)
Facilitating works	✓ (Partial)	✓ (Partial)	✓ (Partial)
Project/design team	✓	✓	✓
Undefined	✗	✗	✗

Table 9: External works scope comparison between different developments

Key: ✓ In Scope ✗ Out of Scope

Subcategory Name	Hamilton Hill	Bushmead	Orion Industrial
Site preparation works	✓	✓	✓
Roads, paths and pavings	✓	✓	✓
Soft landscaping, planting and irrigation systems	✓	✗	✓
Fencing, railings and walls	✓	✓	✓
External fixtures	✓	✓	✗
External drainage	✓	✓	✓
External services	✓	✓	✓
Minor building works and ancillary buildings	✓	✗	✗

It should be noted that soil carbon and carbon sequestration/emissions from vegetation were excluded. This is partly due to a lack of data (species, climate data, and existing soil carbon stocks), but also due to a lack of robust standards for assessing carbon sequestration by soils and flora.

Future assessments could use an independent carbon sequestration modelling tool, such as FullCAM and feed those results into the life cycle assessment to gain a fuller picture whole project life cycle carbon including soil carbon and planting.

8.2 Similarities Between the Sites

Table 10 is a comparison of the life cycle carbon impact of the projects by the life cycle stage. The most striking similarity between the projects is that the largest life cycle impact category is construction. In all three cases, the construction effort is between 28%-33% of the life cycle impacts. As noted in sections 7.1.3, 7.2.3, & 7.3.3 this life cycle stage represents the impact of the construction equipment – predominantly from fuel use.

Table 10: Percentage Impact by Life Cycle Stage

	Hamilton Hill	Bushmead	Orion Industrial
Construction	29.12%	32.22%	27.95%
Products	16.98%	23.62%	14.94%
Transport	10.76%	22.84%	13.73%
Recurring	24.04%	14.99%	27.43%
Energy	9.07%	3.79%	8.57%
End of life	10.03%	2.54%	4.96%

Another interesting finding is that products – that is the materials used (i.e. for roads, retaining, services, etc.) – are only 14%-17% of life cycle carbon impacts for Hamilton Hill and Orion Industrial, while their transport to site is a further 10%-14% of life cycle carbon. These projects minimised the amount of imported fill. On the Bushmead development - which included imported fill – products represented nearly 24% of life cycle carbon, with their transport to the site representing a further 23% of life cycle carbon.

For the Hamilton Hill and Orion Industrial Park developments, recurring impacts are the second highest life cycle carbon impact category. These are maintenance and repair impacts for the roads and landscaped areas. This not only highlights these areas as opportunities to reduce life cycle carbon, but it also demonstrates the importance of assessing whole of life carbon, and not focusing on upfront carbon in isolation.

Operational energy is around 9% of life cycle carbon emissions for Hamilton Hill and Orion Industrial Park. This is predominantly for street lighting, though in the case of Hamilton Hill, there is also operational energy for operating a bore for landscape irrigation.

8.3 Unique Aspects of the Sites

Each of the projects is unique in various aspects. The Hamilton Hill project is on the site of the former Hamilton Senior High School. The decommissioning of the high school afforded the project the opportunity to include significant amounts of reclaimed materials. This can be seen in the environmental strategy performance of this project with 6 of the 10 strategies involving reusing materials from the site. These strategies contributed 6.3% of the 12.1% life cycle carbon reduction for the project.

Unlike Hamilton Hill (and Orion Industrial Park), the Bushmead development is a green field development. And at 88ha, it is also significantly larger than the other developments considered. These two factors are likely contributors to Bushmead requiring more imported fill material than the other two sites. Significantly, the additional imported fill is the reason that product and transport emissions are higher on this project than the other two.

The other unique aspects of the Bushmead development are that it includes 185ha of additional land that is being preserved as natural bushland; and that the developers are minimising newly landscaped areas, which minimises maintenance and water use for irrigation compared to the other sites.

Orion Industrial Park is the only industrial development assessed as part of this study. This means that the lots are significantly larger than the other developments resulting in significantly lower carbon emissions per m^2 (Figure 11(a)), but significantly higher carbon emissions per lot (Figure 11(b)).

We can conclude from this that industrial developments are unique compared to residential developments. So, while there are similarities between the projects – notably in the relative contribution of different life cycle stages, and some individual elements to the life cycle impact – residential developments and industrial developments cannot be directly compared by a common functional unit. Ultimately, it may be possible to create separate benchmarks for residential and industrial developments.

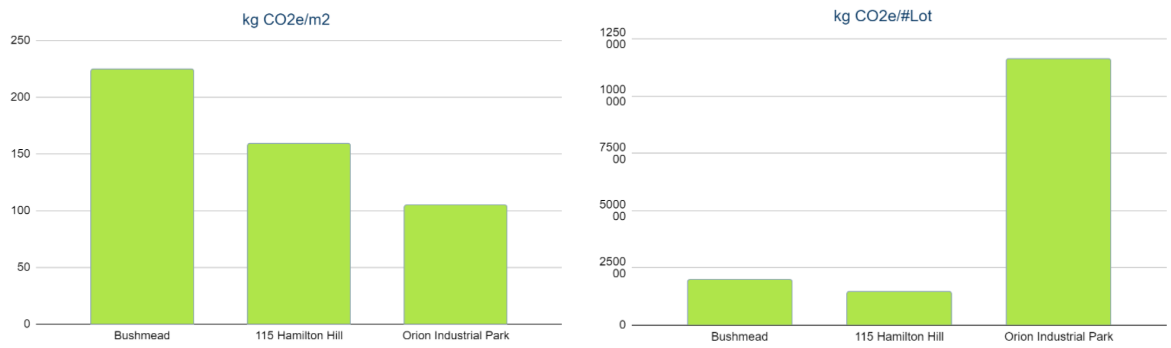

Figure 11(a): Development Carbon Emissions per m² ; Figure 11(b): Development Carbon Emissions per Lot

8.4 Opportunities

Analysis of the life cycle assessment models for the developments has highlighted several commonalities – such as high construction equipment emissions, as well as differences – such as lower materials impact on 2 of the 3 projects. From these, we can identify several opportunities that could be targeted to reduce the life cycle emissions of future developments. Some of these opportunities are available immediately, others may result in higher costs, and others still may only become possible in the future.

Electric Construction Equipment – Construction equipment was found to be the largest single life cycle impact category on all three developments. Scenario modelling indicates that by using electric construction equipment in place of diesel-powered construction equipment, life cycle emissions could be reduced by at least 11% - 18% depending on the type of equipment, overall equipment hours, and the carbon intensity of the electricity grid used to power the equipment.

It is recognised that electric construction equipment is not readily available in Australia at this time and that there will be a substantial cost involved for construction companies to switch their current assets to electric versions. This study, however, highlights the benefits that could be made from making this switch.

Electric Freight Transport – Transport of materials and equipment was found to be between 10% and 23% of life cycle emissions in the three projects. So, similarly, to electrifying construction equipment, electrification of freight transport has the potential to provide substantial benefits in terms of life cycle carbon emissions. Again, it is recognised that electric freight transport options are not readily available in Australia yet, but this study highlights the benefits of making the switch.

Solar Street Lighting – Electricity use for street lighting was in the top 10 individual elements contributing to life cycle emissions for all three projects. Street lighting could be made more efficient, or operate at lower light levels, but switching to solar-powered streetlights is a relatively simple strategy using readily available technology. Scenario modelling indicates this strategy could reduce life cycle carbon emissions by up to 8%.

Minimise Landscaped Areas – Maintenance of landscaped areas was found to be a significant contributor to life cycle carbon emissions for one of the developments and irrigation water was found to be significant in another. Minimising landscaped areas that require ongoing maintenance

– such as mulching – and/or irrigation is an opportunity to reduce life cycle emissions. Lawns in particular require regular mowing and large quantities of irrigation, whereas natural bushland or native, waterwise planting can be virtually maintenance-free and require no irrigation.

Low Impact Materials – Although not the largest impact, several materials feature in the top 10 individual emissions items for the projects. Included are asphalt, concrete, bulk fill, aggregates, and paving and retaining materials. Many of these have lower embodied carbon variants or alternatives. Recycled content asphalt (RAP), and fly-ash concrete mixes can have significantly lower impact than their traditional counterparts.

Reduced Earth Movements on Site – Due to the significance of construction equipment emissions to the overall impact, designing to minimise on-site earth movement may be an effective measure to reduce life cycle emissions. This could be linked to minimising the quantity of imported fill but could also be a further measure of carefully considering finished ground levels. It is, however, recommended that a full life cycle assessment be conducted to quantify benefits in this area, as increased use of retaining walls will offset any gains.

9 Conclusions

The report shows that the Global Warming Potential (GWP) impact of the **Construction phase (module A5)** is the largest contributor to the life cycle impact for all three of the development projects. For OneOneFive Hamilton Hill and Orion Industrial Park, this is followed by **Recurring Impacts (modules B2-B4)**, while for the Bushmead development **Products (modules A1-A3)** are the second largest contributor.

Further analysis reveals:

- '**Construction Equipment – Loader**' is the highest impact individual item for OneOneFive Hamilton Hill,
- And '**Concrete | Unreinforced | Portland Cement Blends**' is the highest impact material for OneOneFive Hamilton Hill,
- '**Construction Equipment – Compactor**' is the highest impact individual item for the Bushmead development,
- And '**Bulk Fill, Sand**' is the highest impact material for the Bushmead development,
- '**Operational Energy - Street Lighting**' is the highest impact individual item for Orion Industrial Park,
- And '**Asphalt 10% RAP'** is the highest impact material for Orion Industrial Park,

In the OneOneFive Hamilton Hill development, 10 strategies were modelled in the Proposed Design, resulting in a 12.1% life cycle reduction in Global Warming Potential, GWP. Of those, the most effective was '**Site Sourced Aggregates, Sand**', followed by '**Water Efficient Irrigation**'.

3 strategies were modelled in the Proposed Design of the Bushmead development resulting in a 0.3% life cycle reduction in Global Warming Potential, GWP. Of those, the '**100% Recycled Road base course**' was the most effective.

5 strategies were modelled in the Proposed Design of Orion Industrial Park resulting in a 3.8% life cycle reduction in Global Warming Potential, GWP. Of those, '**Recycled and locally sourced Aggregate**' was the most effective, followed by '**Locally sourced Limestone for Sub-base**'.

While there were many unique aspects to the projects – emphasising the need to conduct life cycle assessments on future developments – several opportunities were identified for reducing the life cycle carbon emissions of development infrastructure:

- Electric construction equipment,
- Electric freight transport,
- Solar street lighting,
- Minimise imported fill,
- Minimise landscaped areas,
- Low-impact materials, and
- Reduced earth movements on site.

10 Next Steps

These findings emphasise the importance of considering the entire life cycle of a project and integrating sustainable practices into urban land developments.

Encourage a Science-Based Approach**:** You can't improve what you don't measure. Encouraging developers to embed LCA into their process will help them to understand the full scope of environmental impacts, set realistic goals, track progress, demonstrate sustainable efforts, and manage risks.

Foster Collaboration and Integration**:** Collaboration and knowledge sharing among governments, developers, builders, suppliers, consultants, academia, and communities will help to identify pragmatic solutions and best practices. A collective effort will foster innovative solutions and drive industry towards net-zero goals.

Enhance Knowledge, Accuracy, and Standardisation**:** Promoting the development and implementation of standardised methodologies will ensure consistency and comparability across different assessments, enabling stakeholders to benchmark and measure their performance effectively.

Extend Scope to the Entire Precinct**:** Broadening the focus beyond just development infrastructure to encompassing the entire precinct will facilitate a comprehensive understanding of interconnected factors and trade-off opportunities allowing for better decision-making.

Facilitate Informed Decision-making**:** LCA enables design comparisons, measurement of environmental impacts and drives innovation in sustainable land developments. This data-driven approach enhances credibility, cost-effectiveness, and strategic planning.

Training and Professional Development**:** Providing training programs, workshops, and conferences on development best practice guidelines will enhance the knowledge and skills of professionals involved in sustainable land development.

Appendix A: Environmental Indicators Description

Global Warming Potential, GWP

Anthropogenic global warming is caused by an increase in greenhouse gases (GHG) in the Earth's atmosphere. These gases reflect some of the heat radiated from the earth's surface that would normally escape into space back to the surface of the earth. Over time this warms the earth. Common GHGs include CO_2, N_2O, CH_4, and volatile organic compounds (VOCs). Global Warming Potential (GWP) is expressed in equivalent GHGs released, usually in $kgCO_2e$.

Ozone Depletion Potential, ODP

Ozone is formed and depleted naturally in the earth's stratosphere (between 15-40 km above the earth's surface). Halocarbon compounds are persistent synthetic halogen-containing organic molecules that can reach the stratosphere leading to more rapid depletion of the ozone. As the ozone in the stratosphere is reduced more of the ultraviolet rays in sunlight can reach the earth's surface where they can cause skin cancer and reduced crop yields. Ozone Depletion Potential (ODP) is expressed in equivalent ozone-depleting gases (normally kgCFC11e).

Acidification Potential for Soil and Water, AP

Acidification is a consequence of acids (and other compounds which can be transformed into acids) being emitted to the atmosphere and subsequently deposited in surface soils and water. Increased acidity can result in negative consequences for flora and fauna in addition to increased corrosion of manmade structures (buildings vehicles etc.). Acidification Potential (AP) is an indicator of such damage and is usually measured in $kgSO_2e$.

Eutrophication potential, EP

Over-enrichment of aquatic ecosystems with nutrients leading to increased production of plankton, algae, and higher aquatic plants leading to a deterioration of the water quality and a reduction in the value and/or the utilisation of the aquatic ecosystem. Eutrophication is primarily caused by surplus nitrogen and phosphorus. Sources of nutrients include agriculture (fertilisers and manure), aquaculture, municipal wastewater, and nitrogen oxide emissions from fossil fuel combustion.

Photochemical Ozone Creation Potential, POCP

Photochemical Ozone Creation Potential (POCP), commonly known as smog, is toxic to humans in high concentrations. Although ozone is protective in the stratosphere at low levels it is problematic from both a health and nuisance perspective. Plant growth is also affected through damaged leaf surfaces and reduced photosynthesis. POCP occurs when sunlight and heat react with Volatile Organic Compounds (VOCs).

Abiotic Depletion Potential – Elements, ADPE

Abiotic Resource Depletion of Energy (ADPM) is a measure of the extraction and consumption of primary resources from the earth. Such exploitation reduces resources available to future generations and as such must be managed.

Abiotic Depletion Potential – Fossil Fuels, ADPF

Abiotic Resource Depletion of Energy (ARDE) is a measure of the extraction and consumption of non-renewable energy sources (primarily fossil fuels, but also inclusive of other energy sources such as uranium). The primary energy content of non-renewable energy sources, including the embodied energy to extract, process, and deliver the non-renewable fuels, or manufacture, transport and install the renewable generator. Hence there is usually a non-renewable energy content associated with renewable fuels also.

Appendix B: Scenario Summary Tables

The scenario summary table provides the strategies and their relative savings against the Business as Usual.

Table 11: OneOneFive Hamilton Hill – Implemented strategies and their respective savings.

Scenario	GWP	ODP	AP	EP	POCP	ADPE	ADPF
<Business as Usual>							
Recycled Content Asphalt, 10% RAP	1%	1%	0%	0%	0%	0%	1%
Site Sourced Aggregates, Sand	5%	6%	4%	2%	4%	4%	5%
Site Sourced Recycled Bricks	0%	0%	0%	0%	0%	0%	0%
Site Sourced Recycled Timber	0%	0%	0%	0%	0%	0%	0%
Locally Sourced Soil and Mulch	1%	1%	1%	0%	1%	1%	1%
Recycled Retaining Wall Blocks	0%	1%	1%	0%	0%	0%	0%
30% Recycled Aggregate in Concrete	0%	0%	0%	0%	0%	0%	0%
Water Efficient Irrigation	4%	0%	1%	1%	1%	1%	3%
Bore Water Irrigation	1%	0%	0%	0%	0%	0%	1%
Bore Water Construction	0%	0%	0%	0%	0%	0%	0%
<Proposed Design>							

Table 12: Bushmead Development – Implemented strategies and their respective savings.

Scenario	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
<Business as Usual>								
Stormwater HDPE pipes – southern cell	0%	0%	0%	0%	0%	0%	0%	0%
100% Recycled Road Base Course	0%	0%	0%	0%	0%	0%	0%	0%
Repurposed blocks for retaining wall	0%	0%	0%	0%	0%	0%	0%	0%
<Proposed Design>								

Table 13: Orion Industrial Park – Implemented strategies and their respective savings.

Scenario	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
<Business as Usual>								
100% Recycled and Locally Sourced Bulk Aggregates	2%	1%	1%	1%	1%	2%	2%	0%
Recycled Content Asphalt	0%	2%	1%	0%	1%	0%	1%	0%
Local sourcing of Limestone Sub-base to reduce transport	1%	2%	1%	1%	1%	2%	1%	0%
Local sourcing of Limestone for Retaining Wall to reduce transport	0%	0%	0%	0%	0%	1%	0%	0%
Locally Sourced Mulch	0%	0%	0%	0%	0%	0%	0%	0%
<Proposed Design>								

Appendix C: Low-Impact Strategy Details

Various low-impact design strategies were modelled in the LCA study to determine the relative benefits and aid the design decision-making process. Strategies included in each of the development are provided below. The relative saving of each progressed recommendation against the Benchmark is provided in the tables for each strategy.

OneOneFive Hamilton Hill

I. Recycled Content Asphalt, 10% RAP

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Recycled Content Asphalt, 10% RAP	0.91 %	0.73 %	0.45 %	0.22 %	0.37 %	0.43 %	0.94 %

Table 14: Impact savings (or increases) associated with the Recycled Content Asphalt, 10% RAP as a percentage of the Proposed Design.

The recurring impacts of maintaining and replacing asphalt paving are very high. Asphalt alternatives are paving systems that are more durable such as brick, concrete or granite paving which lasts the longest but also has the highest capital costs. These systems are usually also permeable which allows surface runoff to permeate into the ground. Where alternative paving cannot be used, low-carbon asphalt should be considered.

There is a growing number of Recycled Asphalt Pavements (RAP) and recycled content alternatives being used globally. These alternatives can contain various proportions of recycled materials such as glass, plastic, and printer toner cartridges. The strategy models the replacement of a 0% RAP content asphalt with a 10% RAP alternative. Where lower-impact asphalts with high recycled contents are available, transport distances should be carefully considered as products that are not sourced locally may have significantly increased impacts.

II. Site Sourced Aggregates, Sand

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Site Sourced Aggregates, Sand	4.51 %	5.59 %	3.94 %	2.04 %	3.57 %	4.12 %	4.98 %

Table 15: Impact savings (or increases) associated with the Site Sourced Aggregate, Sand as a percentage of the Proposed Design.

Recycled aggregate and sand in landscaping sub-base in place of primary quarried aggregate and sand. Depending on site (or local availability) recycled aggregate can often be a cost neutral (or even cost-benefit) alternative to virgin.

Note aggregates and sand have significant transport impacts, and if a local recycled source cannot be found then local virgin impact may present a more sustainable option. The scenario accounts for transport savings for the local site-sourced aggregate and sand.

III. Site Sourced Recycled Bricks

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Site Sourced Recycled Bricks	0.44 %	0.12 %	0.17 %	0.06 %	0.23 %	0.08 %	0.31 %

Table 16: Impact savings (or increases) associated with the Site Sourced Recycled Bricks as a percentage of the Proposed Design.

Using recycled clay bricks in all masonry walls will provide some carbon savings. Although there is a lot of labour involved in sourcing and cleaning bricks, they can be cost-competitive with new bricks. The aesthetic look of recycled brick is also very popular in architecturally designed buildings.

The strategy models the use of recycled bricks from the stockpiles for the POS brick stair and retaining walls (WT01), toilet block walls, and stair nosing.

IV. Site Sourced Recycled Timber

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Site Sourced Recycled Timber	0.02 %	0.03 %	0.02 %	0.01 %	0.02 %	0.02 %	0.02 %

Table 17: Impact savings (or increases) associated with the Site Sourced Recycled Timber as a percentage of the Proposed Design.

The use of recycled timber sourced onsite is proposed for landscaping items such as benches and playgrounds. While recycled timber does not have significantly better savings compared to virgin sustainably sourced timber, savings associated with transport can be gained.

V. Locally Sourced Soil and Mulch

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Locally Sourced Soil and Mulch	0.74 %	0.95 %	0.58 %	0.29 %	0.60 %	0.67 %	0.81 %

Table 18: Impact savings (or increases) associated with the Locally Sourced Soil and Mulch as a percentage of the Proposed Design.

The landscaping design proposes the onsite sourcing of all soils and approximately 50m^3 of mulch. The remainder of the mulch is to be sourced locally from nearby Fremantle.

Cerclos

VI. Recycled Retaining Wall Blocks

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Recycled Retaining Wall Blocks	0.34 %	0.54 %	0.56 %	0.29 %	0.31 %	0.30 %	0.41 %

Table 19: Impact savings (or increases) associated with the Recycled Retaining Wall Blocks as a percentage of the Proposed Design.

The scenario accounts for the use of recycled materials in retaining wall blocks compared to limestone blocks.

VII. 30% Recycled Aggregate in Concrete

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
30% Recycled Aggregate in Concrete	0.03 %	0.02 %	0.02 %	0.01 %	0.02 %	0.02 %	0.03 %

Table 20: Impact savings (or increases) associated with the 30% Recycled Aggregate in Concrete as a percentage of the Proposed Design.

The strategy accounts for the replacement of 30% concrete aggregate with recycled aggregate crushed on-site. The concrete specified with recycled aggregate includes insitu landscaping concrete, as well as kerbs and pram ramps. Due to the impacts associated with processing recycled aggregates, not much savings can be expected compared to virgin aggregates, though as the material is sourced onsite, significant savings associated with transport can be gained.

VIII. Water Efficient Irrigation

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Water Efficient Irrigation	3.79 %	0.38 %	1.45 %	0.92 %	0.90 %	1.44 %	3.32 %

Table 21: Impact savings (or increases) associated with Water Efficient Irrigation as a percentage of the Proposed Design.

In modelling this strategy savings are based on the average usage for Stage One landscaping, and efficient usage tabled in the OneOneFive Hamilton Hill Community Groundwater Bore Case Study (Water Corporation, 2021). Reference water use is based on 10mm, twice per week applications annually except winter. Water Sensitive Urban Design (WSUD) principles and waterwise practices including drip irrigation and native planting have contributed to savings.

Dripper irrigation saves between 20% and 50% of water use compared to conventional micro sprays. The savings are achieved due to a more direct application of water to the root zone and less evaporation.

IX. Bore Water Irrigation

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Bore Water Irrigation	0.84 %	0.03 %	0.19 %	0.06 %	0.02 %	-0.22 %	0.54 %

Table 22: Impact savings (or increases) associated with the Bore Water Irrigation as a percentage of the Proposed Design.

The strategy accounts for the use of bore water for irrigation in public areas as opposed to the use of mains water. The impacts associated with mains are higher than locally sourced bore water due to the operational processing and supply of potable water as well as the infrastructure associated with the provision.

X. Bore Water Construction

% Changes Against the Benchmark

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF
Bore Water Construction	0.03 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.03 %

Table 23: Impact savings (or increases) associated with the Bore Water Construction as a percentage of the Proposed Design.

The scenario accounts for the proposed use of Bore water during construction as opposed to mains water. 7098 kL is proposed to be offset.

Bushmead Land Development

I. Stormwater HDPE pipes – southern cell

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
Stormwater HDPE pipes – southern cell	0.02 %	0.02 %	0.01 %	0.01 %	0.05 %	0.00 %	0.07 %	0.00 %

Table 24: Impact savings (or increases) associated with the Stormwater HDPE pipes – southern cell as a percentage of the Proposed Design.

Enviropipes Stormwater Pipes from Diameter Nominal (DN) 100mm to DN 900mm are manufactured in accordance with AS/NZS 5065. HDPE is more resistant than PVC, allowing a longer service life as specified on Enviropipe website: "The Water Services Association of Australia (WSAA) Polyethylene Pipeline Code predicts a life in excess of 100 years before major rehabilitation is required"

Source: http://enviropipes.com.au/~enviropipes/storm-water-pipes/corrugated-drainage-and-sewerage-pipes-advantages

II. 100% Recycled Road Base Course

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
100% Recycled Road Base Course	0.25 %	0.40 %	0.44 %	0.34 %	0.35 %	0.44 %	0.32 %	0.00 %

Table 25: Impact savings (or increases) associated with the 100% Recycled Road Base Course as a percentage of the Proposed Design.

Sub-base of road work using 100% recycled concrete aggregates.

The appropriate grade of recycled crushed concrete eco-aggregate can be used almost anywhere natural aggregate is currently used in commercial or domestic projects, including as base-course or sub-base for footpaths/pavements, medium trafficked roads, driveways and other asphalted or sealed surfaces (https://www.auckland-quarry.co.nz/page/recycling-concrete/)

III. Repurposed blocks for retaining wall

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
Repurposed blocks for retaining wall	0.04 %	0.05 %	0.05 %	0.04 %	0.04 %	0.06 %	0.04 %	0.01 %

Table 26: Impact savings (or increases) associated with the Repurposed blocks for retaining wall as a percentage of the Proposed Design.

The backing blocks for the retaining walls are recycled limestone blocks. From the client's information, an estimated 18% of retaining wall blocks are repurposed blocks. It is assumed they have the same transportation distance as blocks made of new materials.

Orion Industrial Park

I. 100% Recycled and Locally Sourced Bulk Aggregates

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
100% Recycled and Locally Sourced Bulk Aggregates	1.77 %	1.08 %	1.31 %	1.01 %	1.10 %	2.13 %	1.50 %	0.00 %

Table 27: Impact savings (or increases) associated with the 100% Recycled and Locally Sourced Bulk Aggregates as a percentage of the Proposed Design.

Recycled aggregate in road sub-base in place of primary quarried aggregate. Depending on site (or local availability) recycled aggregate can often be a cost-neutral (or even cost-benefit) alternative to virgin.

The transport of aggregates is having a significant impact on the project due to their mass and due to the replacement frequency (currently 50 years for some items). Reducing the transport distance by sourcing the aggregate locally will significantly reduce the recurring impacts of the roads.

The modelling assumes products will be sourced from within 10 km as opposed to the 55 km assumed under BAU.

II. Recycled Content Asphalt

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
Recycled Content Asphalt	0.30 %	1.55 %	0.56 %	0.20 %	0.52 %	0.15 %	1.23 %	0.00 %

Table 28: Impact savings (or increases) associated with the Recycled Content Asphalt as a percentage of the Proposed Design

The recurring impacts of maintaining and replacing asphalt paving are very high. Asphalt alternatives are paving systems that are more durable such as brick, concrete, or granite paving which lasts the longest but also has the highest capital costs. These systems are usually also permeable which allows surface runoff to permeate into the ground. Where alternative paving cannot be used, low-carbon asphalt should be considered.

There is a growing number of Recycled Asphalt Pavements (RAP) and recycled content alternatives being used globally. These alternatives can contain various proportions of recycled materials such as glass, plastic, and printer toner cartridges. The strategy models the replacement of a 0% RAP content asphalt with a 10% RAP alternative. Where lower-impact asphalts with high recycled contents are available, transport distances should be carefully considered as products that are not sourced locally may have significantly increased impacts.

III. Local sourcing of Limestone Sub-base to reduce transport

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
Local sourcing of Limestone Sub-base to reduce transport	1.28 %	1.56 %	1.27 %	0.87 %	1.27 %	2.07 %	1.30 %	0.00 %

Table 29: Impact savings (or increases) associated with the Local sourcing of Limestone Sub-base to reduce transport as a percentage of the Proposed Design.

The transport of the limestone sub-base is having a significant impact on the project due to its mass and due to the replacement frequency (currently 50 years). Reducing the transport distance by sourcing the material locally will significantly reduce the recurring impacts of the roads.

The modelling assumes products will be sourced from within 10 km as opposed to the 55 km assumed under BAU. The Limestone is sourced from Stone Ridge Quarries, Hope Valley WA.

IV. Local sourcing of Limestone for Retaining Walls to reduce transport

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
Local sourcing of Limestone for Retaining Wall to reduce transport	0.36 %	0.44 %	0.36 %	0.25 %	0.36 %	0.59 %	0.37 %	0.00 %

Table 30: Impact savings (or increases) associated with the Local sourcing of Limestone for Retaining Walls to reduce transport as a percentage of the Proposed Design.

The transport of limestone blocks is having a significant impact on the project due to their mass. Reducing the transport distance by sourcing the blocks locally will significantly reduce the recurring impacts of the roads.

The modelling assumes products will be sourced from within 10 km as opposed to the 55 km assumed under BAU. The Limestone is sourced from Stone Ridge Quarries, Hope Valley WA.

V. Locally Sourced Mulch

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPE	ADPF	Mtot
Locally Sourced Mulch	0.13 %	0.14 %	0.13 %	0.09 %	0.13 %	0.21 %	0.12 %	0.00 %

Table 31: Impact savings (or increases) associated with the Locally Sourced Mulch as a percentage of the Proposed Design.

The mulch to be used for Landscaping works is sourced from material extracted from land clearing within Orion Industrial Estate.