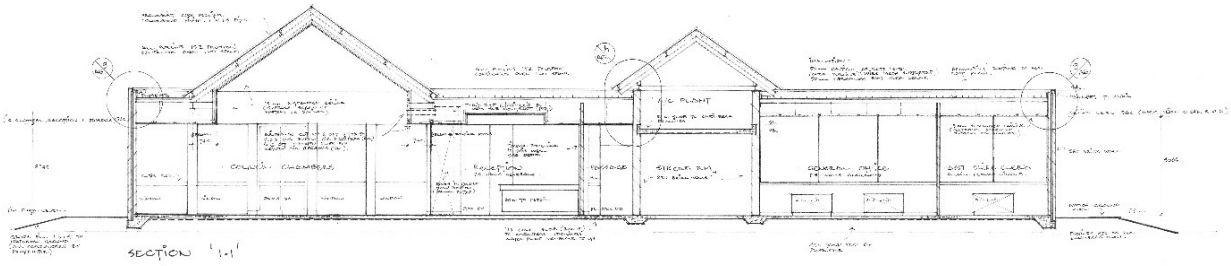
Office of Regional Architecture

CASE STUDY 1

Shire of Narembeen Administration Office Refurbishment

Embodied carbon calculation, modules A1–A5

Tuan Ngo, Director · Version 2 (revised), October 2026



Hand-drawn section through the Shire of Narembeen Administration Office.

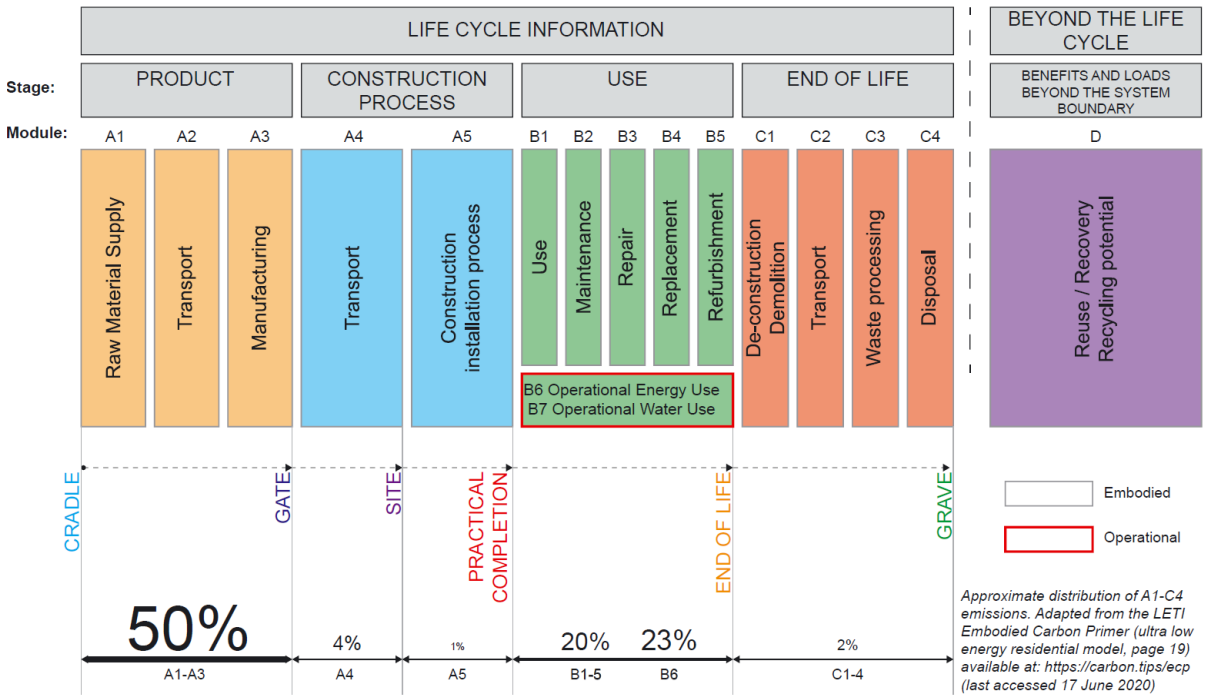
Background

As part of ORA Sustainable Practice Development, we decided the largest impact we can contribute to the built environment is the reduction of Carbon Emission. And at the time of writing of this article, Embodied Energy becoming the most urgent issue to be addressed. We also discover there is a lack of free comprehensive guide, database and examples for the embodied measurement in Australia without using 3rd parties' platforms. We decided to embark on our own journey to conduct the embodied calculation using all available resources to learn and form part of our design decision making process in relate to sustainability.

Introduction

The case study in accordance with BS EN 15978 : 2011 (Assessment of Environmental performance of building and BS EN 15804 : 2019 (relate to EPD), which are used to define the amount of carbon released at different stages of a material or product life (Figure 1) from '*A brief guide to calculating embodied carbon' by www.thestructuralengineer.org*

FIGURE 1:
Lifecycle stages and modules



As we can see from Figure 1, modules A1 to A5 (embodied carbon) are estimated to be more than half of the embodied emission of the building during its life. The production of many common construction materials, such as cement, brick, steel, and aluminium, is expected to rely on fossil energy for quite a long time in future while the world is improving the efficiency of building operational energy and decarbonise electricity grid, the share of the embodied carbon only increases. Moreover, embodied energy is spent upfront, while operation energy is spent over a period of time. Addressing the upfront carbon becomes obvious in addressing the urgency of climate change and global warming potential.

Having said that, we recognise that the operation energy of the building (B1 – B5) still needs to be addressed especially in Australia; it is not the scope of this case study. Also, improving the thermal performance of the building has a diminishing return on both cost and carbon emission. Therefore, we will explore the balance between embodied and operation energy in a separate case study.

The embodied energy calculation in this case study is based on all the final documents for the Certificate of Design Compliance. During Design and Documentation, we considered many aspects of reducing the carbon footprint, from reducing and reusing to material choices, while balancing the Client brief and expectations and general good design. We will discuss these carbon emissions savings in our calculations.

We will also compare the Refurbishment with a New Construction of the same footprint to examine the differences in Embodied Carbon to further discuss our ethos in retaining and protecting existing building stock.

Data sources, assumptions and limitations

As we learned during the process of this case study, not many construction materials in Australia have an Environmental Product Declaration (EPD). We only found and used the below Australian EPD in our calculation:

- Colorbond steel for roofing and walling – BlueScope steel
- Bondor roofing and walling panels
- Dulux Enviro02
- Rondo Products: Ceiling, Wall Framing and Finishing
- Fibre Cement Products from James Hardie Pty Ltd
- Knauf plasterboard Sheetrock HD13mm
- Laminex EPD-Melteca-Whiteboard-Particleboard Substrate-v1-1Mar24
- EPD – Hardwood Timber Wood Solution
- EPD – Softwood Timber Wood Solution
- EPD – Particleboard Wood Solution

Some materials and systems are extrapolated from other EU, US and International EPD:

- Translucent façade systems ‘Danpalone Façade Cladding” Everlite Concept
- Kilon Multiwall Panel: Kingspan Light + Air
- Multiwall Polycarbonate sheets: European Polycarbonate Sheet Extruders
- Aluminium & Window Systems: Altus Industrial Aluminium & Window Systems
- Tasman Insulation: Pink Batts glass wool insulation
- uPVC profiles for windows, doors and façade system: Thermalplastiki S.A.
- EPD Nylon on EcoFlex One – Mohawk Group Premium Modular Backing System
- EPD - Forbor Allura Flex Resilient Heterogeneous Vinyl floor Covering on Foam

The remaining materials, A1-A3, are from the NABERS National Emission Factor (EF) Data Base, with ‘uncertainty adjusted’ as the default. These EFs are considered higher than some other sources.

For example, C32/40 Concrete has A1-A3 ECF of 0.120 kgCO2e/Kg from the Table 2 of *‘A brief guide to calculating embodied carbon’ of www. thestructuralengineer.org*

compared to the equivalent to 32Mpa Concrete has 0.195kgCO2e/kg in Australia from NABERS National Emission Factor Data Base.

Similarly, with Reinforce steel from the 2 sources: 1.99kgCO2e/Kg vs 3.65kg CO2e/Kg

We have not investigated the reasons for these differences and decided to take a precautionary approach.

Some materials such as door hardware, fixing, calking etc not been accounted for.

We made assumption that most existing wiring is retained, large part of existing air-conditioning services is retained. Hence, Services (Hydraulic, Mechanical and Electrical) emission is half of NABER m^2 figure for Building Services of Office low rise.

Calculations

Note: Our Excel spreadsheet is available upon request. We kindly ask that you acknowledge us when using our spreadsheet and share your final product spreadsheet in return.

Default transport emission factor (Module A4)

Emissions from material transportation to the site (A4) are complex but worth discussing. Perth, the most isolated metropolitan area in the world, contributes significantly to its emissions from importing and exporting its products. A significant factor, and worth mentioning, is that it's steel, aluminium and glass products, are mostly imported from Asia, such as China, Korea, Malaysia, etc. At the same time, most of it is exported as raw minerals such as iron ore. Australian-made steel currently comes from the Eastern States; steel products in the Perth Metro and surrounding regions come from long distances. Similarly to aluminium extrusion and aluminium billet, fibre cement sheets. Polycarbonate sheet (Danpalon brand) comes from Israel, which has the longest distance and highest Transportation emission per kg which will be discussed in detail in the report.

The project is in Narembeen 285km from Perth. Many materials and trades travel long distances to the site, predominantly using trucks. This significantly contributes to the transport of embodied carbon (A4). There is also travel cost for the contractors; we assumed the contractor would source the closest material supplier and trade to increase their profits and for practical and technological reasons such as concrete time travel from plant to site.

Materials locally produced (Perth Metropolitan) are concrete, brick and concrete block, plasterboard (Gyprock) and some timbers. The two closest concrete plants supplying commercial-grade concrete are approximately 55km from the site; other Australian-made products are Fibre Cement Sheet and most timbers, assuming the Eastern States. All other materials are assuming coming from Asia with various logistical routes and variations. We calculated our default over sea product produced in Shanghai and shipped to Fremantle Port. We also assume all hot roll steel sections and steel reinforcement products are imported from Asia due to their cost competitiveness.

We acknowledge that due to the complex logistical routes involved in manufacturing Steel sheet products (roofing, cladding and lightweight frames) in Australia, the A1-A3 included the average transport emissions across all states. We assumed the same product supplied to the Eastern State would have much lower transport emissions than Western Australia. As a result, we conservatively include a 4000km rail emission factor in A4 module for Colorbond and 4000km 40t truck emission for Rondo steel products.

Majority of all other materials such as aluminium and glass is either from Asia or Easten state (by truck)

While this is a simplification, we feel it gives us the closest estimate for the exercise without knowing all the details.

Transport mode emission based on *the Table 1: Freight emission factors from 'Upfront Carbon Emissions calculation guide – interim' of Green Building Council Australia*

Table 1: Freight emission factors

Freight type	Carbon footprint per tonne-kilometre (kg CO2e/tkm)	Source
Air, domestic	1.86	AusLCI v1.38
Air, international	1.65	AusLCI v1.38
Rail	0.0240	AusLCI v1.38
Van, 3.5t gross weight	1.54	AusLCI v1.38
Truck, 3.5 to 16t gross weight	0.216	AusLCI v1.38
Truck, 16 to 28t gross weight	0.128	AusLCI v1.38
Truck, 28t gross weight	0.0719	AusLCI v1.38
Truck, 40t gross weight	0.0686	AusLCI v1.38
Ship, container ship	0.0161	Defra (2022)
Ship, bulk carrier	0.00354	Defra (2022)

Local supply by small trucks up to 16t: 55km x 0.216 KgCO2e/tkm = 0.01188 kgCO2e/kg

Perth metro supply by truck up to 16t: 300km x 0.216 KgCO2e/tkm = 0.0648 KgCO2e/kg

Australian made product from eastern states with 40t truck: 4000km x 0.0686 KgCO2e/tkm = 0.2744 kgCO2e/kg + local distribution from Perth by 16t truck = 0.3392 kgCO2e/kg

Australian made products from eastern states with rail (for BlueScope steel only): 4000km x 0.024 KgCO2e/tkm = 0.2744 kgCO2e/kg + local distribution from Perth by 16t truck = 0.1608 kgCO2e/kg

Import product from Asia (Shanghai Port): Internal 40t truck of 145km, 9000km container ship, 45km local 40t truck to Warehouse in Welshpool: 190km x 0.0686 KgCO2e/tkm + 9000km x 0.0161 KgCO2e/tkm = 0.157 kgCO2e/kg + local distribution from Perth by 16t truck = 0.222734 kgCO2e/kg

Import product from Israel (Danpalon sheet only): Internal 40t truck of 105km, 28620km container ship, 45km local 40t truck to Warehouse in Welshpool: 150km x 0.0686 KgCO2e/tkm + 28620km x 0.0161 KgCO2e/tkm = 0.157 kgCO2e/kg + local distribution from Perth by 16t truck = 0.535872 kgCO2e/kg

Construction process and construction waste emission (module A5a and A5w)

The calculation method for modules A5a and A5w is complex. For example, From *page 23 of 'A brief guide to calculating embodied carbon' by www.thestructuralengineer.org*

The A5w emissions factor accounts for the carbon emissions released during production, transportation, and disposal of wasted material. The factor itself represents the percentage estimate of how much of the material brought to site is wasted (using a waste factor, WF) so that the A5w factor can be multiplied by the same material quantity used for the A1–A3 calculations. The A5w factor is derived by multiplying the WF by the sum of the relevant ECFs:

A5w = WF × (A13 + A4 + C2 + C34)

It is difficult to obtain accurate data for the calculation especially for A5a. Some EPDs provide A5 components, while others do not. We calculated A5a and A5w based on the split on the *Table 7 (page 33) of 'Embodied*

Carbon & Embodied Energy in Australia's Buildings' by Green Building Council Australia and Thinkstep-anz' for Department of Industry, Science, Energy and Resources, Commonwealth of Australia.

This means our calculation of A5 is based on an average of the Australian construction industry in proportion to A1-A3.

We note the forecast reduction of A5a and between 2019 to 2050 due to the decarbonation of the grids, transportation and construction tools and slight increase A5w.

For non-residential buildings, A5a is 20.00% of A1-A3 in 2019 compared to 2.75% in 2050

A5w is 1.50% of A1-A3 in 2019 compared to 1.69% in 2050

We extrapolate the proportion of A5a and A5w (linear interpolation) for expected construction in 2025: A5a to be 15.94% of A1-A3 and A5w to be 1.54%. (Revision, October 2026: version 1 of this paper used the residential split, 20.66% and 1.52%; as the building is an office, the non-residential split now applies.)

Result discussion

The total upfront emission is 113.0 ton CO_2 E, which is made up of:

- A1-A3 = 89.1 ton CO_2 E
- A4 = 8.3 ton CO_2 E or about 9% of A1-A3.
- A5a = 14.2 ton CO_2 E (estimate proportion base on percentage of A1-A3)
- A5w = 1.4 ton CO_2 E (estimate proportion base on percentage of A1-A3)

As the building is approximately 540 m^2 the emission per m^2 is 209kg CO_2 which is about 18% lower than the average refurbishment emission of 255kg CO2/m^2

A4 emissions are significantly higher than the national average of 1.88% of A1-A3 (non-residential, 2025). This indicates the transportation impact of a rural project and the lack of local manufacturing in Western Australia.

The calculation also highlights the large impact of concrete (5.5 ton CO_2), masonry (3 ton CO_2), structure steel (3.6 ton CO_2), aluminium glazing (13.7 ton CO_2) despite being a small portion of the project in area

- Concrete floor impact: 200kgCO_2/m^2
- Double clay brick wall: 141kgCO_2/m^2
- Single 90mm blockwork wall: 57kgCO_2/m^2
- Aluminium glazing system: 504kg CO_2/m^2 for double glazed and 452kg CO_2/m^2 for single glazed. Predominantly contributed from aluminium using a figure from NABER database with the uncertainty factor at 34.2kg CO_2/kg. Despite Capral product using LocAL aluminium billet, which is 8kg CO_2/kg compared to 12.46kg CO_2/kg global average, without EPD, the possible reduction is only 4.46KgCO2 which is about 10% or about 1ton CO2 saving for this project.

Other significant emission contributions are from internal finishes due to their large quantity such as acoustic board lining (5.3 ton CO_2), wall tiling (1.6ton), solid core timber door (1.8ton), carpet (1.9 ton CO_2), furniture and cabinetwork (16.9 ton CO_2) and MEP services (13.1 ton CO_2)

Despite this, refurbishing an existing building is still much more economical, both financially and environmentally. It is estimated that the same size new building would emit approximately 291 tons of CO2, or about 2.6 times more than refurbishment, not including demolition of the existing building (based on 538 KgCO2e/m^2 *Table 7 (page 33) of 'Embodied Carbon & Embodied Energy in Australia's Buildings' by Green Building Council Australia and Thinkstep-anz' for Department of Industry, Science, Energy and Resources, Commonwealth of Australia.*)

Design consideration in carbon reduction

Without changing the scope and client requirement of the project, the following actions were taken to reduce embodied carbon emissions in total of 20.7 ton (about 18% of total emission):

a) Reuse, relocate and refurbish existing timber doors and door frames. 9 doors out of 14 doors and timber frame were existing, resulting in 3.24 tonCO2 saving
b) Using hardwood frames for internal windows and door frames internally instead of aluminium for a saving of 341kg CO_2
c) External timber stud and steel stud frame wall instead of double cavity brick wall resulting in 537kg and 1.2 tonCO2 saving
d) Internal timber stud frame wall instead of the single brick wall resulting in 3.8 tonCO2 saving
e) Specify local window aluminium supplier - Capral with LocAL aluminium resulting in approx. 1.3 tonCO2 saving
f) Specify local carpet supplier – GH Commercial with sustainability credentials resulting in approx. 10 tonCO2 saving (emission factor estimated based on EPD in USA of equivalent product)
g) Specify local Vinyl supplier – Forbo with sustainability credentials resulting in approx. 405kg CO2 saving.

Other potential emission savings could be extensive use of timber for the courtyard roof structures. However, with the lack of skilled trade in the industry, it would be cost prohibitive. Other areas are the use of timber for external windows, and doors instead of aluminium. However, with the lack of resources and systems for regular maintenance, external timbers would potentially be problematic for the client. The other alternative would be uPVC doors and windows; however, they are generally not available or warranted for commercial project.

Conclusion

“Strive for Progress, not Perfection”

We are proud to have taken this step despite the difficulty and extra cost to our operation. We strive to be at the frontier in sustainability.

Although our calculations might contain inaccuracies and errors, we trust our figures are within an acceptable margin of error. More importantly, it gives us a clear guide to reducing upfront emissions through reduced, reused, or selected material. It also highlights the low-hanging fruit and immediate actions we can take.

There would be always room for improvement, and we are excited to have developed a database and insights of material and system for our next project in reducing embodied carbon emissions.

The numbers are also valuable in our discussions with our peers, clients, sub-consultants, suppliers, and contractors to move the industry in the right direction.

And finally, the number is our benchmark to measure our progress in the future.

References

- The Institution of Structural Engineers (2020). “How to calculate embodied carbon, second edition”
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- Simona Fischer, Lauren Gardner, Emily Gross, Veronica McCracken, Java Nyamjav. MSR Design. “Embodied Carbon in Commercial Furniture: Introducing a calculator, a case study and a new set of baseline”.
- Capral Aluminium. (2024) Whitepaper. “LocAL: Lower-Carbon Aluminium for Australian Manufactures”

Err:522									Refer to A4 Emission Factor Calcuation						(assuming 50km) 0.005 KgCO2e/kg	1.77kgCO2e/kg for timber, 0.13kgCO2e/kg for others							
	Number	Linear m	Area (m2)	Volume (m3)	Weight (kg)	A1-A3 ECF kgCO2e/unit	A1-A3 kgCO2e	A1-A3 kgCO2e/m2 or kgCO2e/m for linear material	A4 Transport ECF kgCO2e/kg	A4 Transport KgCO2e	A4 Transport KgCO2e/m2	A5a (2025) 15.94% (non-res) of A1-A3	A5w (2025) 1.54% (non-res) of A1-A3	Waste factor	C2 transport ECF kgCO2e	C3-C4, waste processing ECF kgCO2e	A5w factor	A5w kgCO2e	Total EC kgCO2e	Total EC tonCO2e		Reduction area from construction efficiency	New Total EC tonCO2e
Conc slab 100mm min 25Mpa up to 32Mpa			62.00	6.20	14,880.00	0.20	2,902	46.80	0.01	177				4%	0.005	0.13	0.01	203.49	3,281.86	3.28		31	
with 300 thicken edge			9.45	2.83	6,803.14	0.20	1,327	140.40	0.01	81				4%	0.005	0.13	0.01	93.03	1,500.47	1.50			
Reo SL72 (kg)			62.00		176.51	**3.65**	644	10.39	0.22	39				4%	0.005	0.13	0.16	28.30	711.89	0.71			
Concrete pad footing to column and infill under floorboxes				0.96	2,292.00	0.20	447		0.01	27				4%	0.005	0.13	0.01	31.34	505.51	0.51			
Hot roll Steel structure - galvanised,Plus steel misc (5%)					900.00	4.09	3,681		0.22	200				0%	0.005	0.01	0.00	3.89	3,885.36	3.89			
ROOF																							
Shadowline 305 roof sheet, Colorbond (EPD)			27		264.87	31.774	858	31.77	0.1608	43	1.58			15%									
Flashing 0.55 BMT flat, Colorbond (EPD)			105		470.4	15.1	1,586	15.10	0.1608	76	0.72			15%									
Danpalon 16mm system			57		358.302	35.444	2,020	35.44	0.535872	192	3.37			10%									
Bondor Solar Span 100mm EPS (EPD)			11		124.3	44.1	485	44.10	0.0648	8	0.73			15%									
GLAZING SYSTEM																							
Double glazed operable			18.7				9,441	504.89															
Double glazed glass only			18.7		461.89	2.38	1,099	58.79	0.222734	103													
Double glazed aluminium only			18.7		280.5	29.74	8,342	446.10	0.222734	62													
Double glazed fixed			8				4,084	510.48															
Double glazed glass only			8		226.4	2.38	539	67.35	0.222734	50				1%									
Double glazed aluminium only			8		119.2	29.74	3,545	443.13	0.222734	27				1%									
Single glazed system with alu frame			0.7				316	452.06		6	8.21												
Alumium frame only		4.9	0.7		9.8	29.74	291	416.36	0.222734	2				1%									
Glass only Soltech 6mm			0.7		10.5	2.38	25	35.70	0.3392	4				1%									
Single glazed system with jarrah frame			8							54	6.78												
Jarrah frame only		24		0.2088	171.216	591	123	5.14	0.0648	11				10%									
Glass only Vlam Hush 6.5mm thick			8		127.2	2.38	303		0.3392	43				1%									
Replacement glazing Vlam Hush 6.5mm			3		47.7	2.38	114	37.84	0.3392	16	5.39			1%									
WALL																							
Double brick cavity wall (to new opening)			1	0.22	314.6	0.449	141	141.26	0.0648	20	20.39			5%									
External 90 steel stud, FC cladding+lining			11				361	32.82		110	10.01												
92mm steel stud 0.55 BMT Rondo251		33			26.0	3.29	85	2.59	0.3392	9				15%		0.00639							
35mm batten Rondo M735		26.4			28.7	3.09	89	3.36	0.3392	10				15%		0.00639							
8mm external cladding			11		145.2	8.1	89	8.10	0.3392	49				15%		1.4							
6mm internal lining			11		95.7	6.05	67	6.05	0.3392	32				15%		1.19							
90mm R2.8 glass wool insulation			11		26.73	0.96	26	2.33	0.3392	9				10%									
External enamel paint			11		2.2	0.5	6	0.50	0.3392	1				1%									
External 90 timber stud, FC cladding+plaster			4.2				55	13.03		38	9.17												
90mm timber stud with noggings		14.28		0.044982	24.8	-764	-34	-2.41	0.3392	8				15%		0.00639							
35mm batten Rondo M735		10.08			11.0	3.09	34	3.36	0.3392	4				15%		0.00639							
8mm external cladding			4.2		55.44	8.1	34	8.10	0.3392	19				15%		1.4							
13mm plasterboard lining			4.2		54.6	1.83	8	1.83	0.0648	4				15%		1.19							
90mm R2.8 glass wool insulation			4.2		10.206	0.96	10	2.33	0.3392	3				10%									
External enamel paint			4.2		0.84	0.5	2	0.50	0.3392	0				1%									
Internal paint			4.2		0.84	0.392	2	0.39	0.3392	0				5%									
Internal 90 timber stud wall, plaster lining		21	56.7				86	4.12		89	4.26												
90mm timber stud with noggings		71.4		0.22491	123.9	-764	-172	-2.41	0.0648	8				10%									
13mm plasterboard lining (Knauf)			56.7		481.95	1.83	104	1.83	0.0648	31				15%		1.19							
90mm R2.8 glass wool insulation			56.7		137.781	0.96	132	2.33	0.3392	47				10%									
Internal paint x 2			56.7		9.9225	0.392	22	0.39	0.3392	3				5%									
Internal blockworks 90mm		17	49.3	4.437	10648.8	0.264	2,811	57.02	0.0648	690	14.00			5%									
Internal plaster lining (13mm)(Knauf)		132	356.4		3029.4	1.83	652	1.83	0.0648	196													
Internal plaster painting		202	545.4		95.445	0.392	214	0.39	0.3392	32													
Accoustic board lining		209	604.83		1814.49	8.69	5,256	8.69	0.3392	615													
FINISHES																							
Ceiling plaster			79		671.5	1.83	145	1.83	0.0648	44													
Ceiling steel system-Rondo		237			257.6	3.09	796	3.36	0.3392	87													
Ceiling painting			435		76.125	0.392	171	0.39	0.3392	26													
Water proofing			93		46.5	0.46	21	0.23															
Wall tilling 8mm			90		1620	0.984	1,594	17.71	0.222734	361													
Jarrah timber door frame		33		0.396	291.06	-731	-289	-8.77	0.0648	19													
Timber door new			16	0.64	352.6	111	1,776	111.00	0.3392	120													
Door paint new			32		5.6	0.392	13	0.39	0.3392	2													
Door hardware (not accounted for)									0.222734	0													
External spandrel painting			25		4.375	0.5	13	0.50	0.3392	1													
Carpet (GH Commercial)			355		276.9	5.3	1,882	5.30	0.222734	62													
New Hardwood timber skirting 100mm x 18mm		47		0.0846	62.181	591	50		0.0648	4													
Vinyl (Forbo Allura Flex)			19		52.82	16.6	315	16.60	0.222734	12													

Floor tiles (8mm)			19		342	0.984	337	17.71	0.222734	76													
Moisture treatment to concrete floor - Aquron2000			372		82.666666667	0.46	38	0.10	0.222734	18													
Building services MEP Office lowrise (half for refub)			460		9742.8	1.345	13,104	28.49	0.3392	3,305													
Furniture fitout									0.222734	0													
Benchtop - Corian			0.62			67.5	42																
Laminate Particle board			312			-6.22	-1,941																
Furniture fitout - Steel legs				0.48	3768	4	15,072		0.222734	839													
Furniture chairs	52				260	72	3,744		0.222734	58													
TOTAL CO2							**89,132**			**8,285**		**14,204.59**	**1,375.59**										**112,997**
CO2/m2							165.06			15.34		26.30	2.55										209.25
NEW BUILT COMPARE			**540**																				**289,980**
																							537.00
Brick veneer wall with steel stud			1				83	82.95															
Single brick			1	0.11	157.3	0.449	71	70.63	0.0648	10													
92mm steel stud 0.55 BMT Rondo251		3			2.4	3.29	8	2.59	0.3392	1													
13mm internal lining			1		8.7	1.83	2	1.83	0.3392	3													
90mm R2.8 glass wool insulation			1		2.43	0.96	2	2.33	0.3392	1													
External enamel paint			1		0.2	0.392	0	0.39	0.3392	0													

Ref: Table 7 (page 33) of 'Embodied Carbon & Embodied Energy in Australia's Buildings' by Green Building Council Australia and Thinkstep-anz' for Department of Industry, Science, Energy and Resources, Commonwealth of Australia.

		x1		x2			x	
		2019	Proportion to A1-3	2050	Proportion to A1-3	Slope value (m)	2025	Proportion to A1-3
Residential (y1 and y2)	A1-A3	9.43	100.00%	12.85	100.00%	0.1103226	10.09	100.00%
	A4	0.19	2.01%	0.32	2.49%	0.0041935	0.22	2.13%
	A5a	2.47	26.19%	0.48	3.74%	-0.0641935	2.08	20.66%
	A5w	0.14	1.48%	0.21	1.63%	0.0022581	0.15	1.52%
	C2	0.05	0.53%	0.08	0.62%	0.0009677	0.06	0.55%
	C3-C4	0.07	0.74%	0.13	1.01%	0.0019355	0.08	0.81%
	Total	12.35	130.97%	14.07	109.49%	0.0554839	12.68	125.67%
Non-residential (y1 and y2)	A1-A3	7.35	100.00%	9.44	100.00%	0.0674194	7.75	100.00%
	A4	0.13	1.77%	0.21	2.22%	0.0025806	0.15	1.88%
	A5a	1.47	20.00%	0.26	2.75%	-0.0390323	1.24	15.94%
	A5w	0.11	1.50%	0.16	1.69%	0.0016129	0.12	1.54%
	C2	0.03	0.41%	0.05	0.53%	0.0006452	0.03	0.44%
	C3-C4	0.04	0.54%	0.06	0.64%	0.0006452	0.04	0.57%
	Total	9.13	124.22%	10.18	107.84%	0.0338710	9.33	120.36%

Linear interpolation

Step 1 $m = (y2 - y1) / (x2 - x1)$

Step 2 $y = y1 + m \cdot (x - x1)$

A4 Default Transport Emission

Project location:	Narembeen
Distance from Perth	300
Concrete plants distance	55

	Distance 1 Km	Emission 1 KgCO2e/tkm	Distance 2 Km	Emission 2 KgCO2e/tkm	A4 EF KgCO2e/kg
Local supply 16t truck	55	0.216			0.01188
Perth supply 16t truck	300	0.216			0.0648
Eastern States product (truck)	4000	0.0686			0.3392
Eastern States product (rail)	4000	0.024			0.1608
Oversea Product (Shanghai)	190	0.0686	9000	0.0161	0.222734
Oversea Product (Israel)	150	0.0686	28620	0.0161	0.535872

Material EF Conversion

Roof sheet - Bluescope - EPD

	Mass kg/m2	A1-A3 total /m2 inc rollforming	A4	A5
0.70BMT flat Colorbond	5.65	18.3		
Shadowline 305 Colorbond	9.81	31.774		
0.55BMT flat Colorbond	4.48			
Kingspan Multiwall				
10mm	1.75			
			Israel	
Danpalon 16mm system	6.286	35.444	0.535872	

Capral aluminium windows

	Description	Net Weight in Kg	Kg/m	m	m2	Kg	kg per m2
Frame	ETB0213 6060 T5 6.5m ALF Mill Finish	17.875	2.75	7.2		19.8	
Cover Bead	ETB0205 6060 T5 6.5m Mill Finish	3.692	0.568			0.0	
Flush Filler	EP14756 6060 T5 6.5m Mill Finish	2.464	0.379076923	10.8		4.1	
Cover Sill/Transom	ETB0214 6060 T5 6.5m ALF Mill Finish	15.34	2.36	3.9		9.2	
Internal Bead	ETB0217 6060 T5 6.5m Mill Finish	4.973	0.765076923			0.0	
Internal Sill/Transom	ETB0216 6060 T5 6.5m ALF Mill Finish	15.665	2.41	3.9		9.4	
Male Mullion	ETB0218 6060 T5 6.5m ALF Mill Finish	16.77	2.58	18.6		48.0	
Female Mullion	ETB0219 6060 T5 6.5m ALF Mill Finish	12.805	1.97			0.0	
Sub Frame	ETB0018 6060 T5 6.5m ALF Mill Finish	9.191	1.414	1.8		2.5	
Sub frame bead	EPD0504 6060 T5 6.5m Mill Finish	1.612	0.248	1.8		0.4	
Sub Head	ETB0016 6060 T5 6.5m ALF Mill Finish	10.303	1.585076923	3.9		6.2	
Sub Sill	ETB0017 6060 T5 6.5m ALF Mill Finish	9.854	1.516	3.9		5.9	
Total aluminium						**105.6**	**15.03858**
Double Glaze 6+6 m2					**5.8**	**174**	**24.78632**

W5 full operable, 2 mullion

Height m 1.8

Length m 3.9

total m2 7.02

	Description	Net Weight in Kg	Kg/m	m	m2	Kg	kg per m2
Frame	ETB0213 6060 T5 6.5m ALF Mill Finish	17.875	2.75	4.28		11.8	
Cover Bead	ETB0205 6060 T5 6.5m Mill Finish	3.692	0.568			0.0	
Flush Filler	EP14756 6060 T5 6.5m Mill Finish	2.464	0.379076923			0.0	
Cover Sill/Transom	ETB0214 6060 T5 6.5m ALF Mill Finish	15.34	2.36			0.0	
Internal Bead	ETB0217 6060 T5 6.5m Mill Finish	4.973	0.765076923			0.0	
Internal Sill/Transom	ETB0216 6060 T5 6.5m ALF Mill Finish	15.665	2.41			0.0	
Male Mullion	ETB0218 6060 T5 6.5m ALF Mill Finish	16.77	2.58			0.0	
Female Mullion	ETB0219 6060 T5 6.5m ALF Mill Finish	12.805	1.97			0.0	
Sub Frame	ETB0018 6060 T5 6.5m ALF Mill Finish	9.191	1.414	1.24		1.8	
Sub frame bead	EPD0504 6060 T5 6.5m Mill Finish	1.612	0.248	1.24		0.3	
Sub Head	ETB0016 6060 T5 6.5m ALF Mill Finish	10.303	1.585076923	0.9		1.4	
Sub Sill	ETB0017 6060 T5 6.5m ALF Mill Finish	9.854	1.516	0.9		1.4	
Total aluminium						**16.6**	**14.89413**
Double Glaze 6+6 m2					**1.0527**	**31.581**	**28.29839**

W7 fixed

Height m 1.24

Length m 0.9

total m2 1.116