Department of Climate Change, Energy, the Environment and Water

How to Calculate Embodied Carbon of a Concrete Mix

Fact sheet

Rev 01 May 2024

Published by Department of Climate Change, Energy, the Environment and Water, NSW

Authored by Arup Australia, based on a collaboration with DCCEEW

NSW GOVERNMENT

Acknowledgment of Country

We acknowledge that Aboriginal and Torres Strait Islander peoples are the First Peoples and Traditional Custodians of Australia, and the oldest continuing culture in human history.

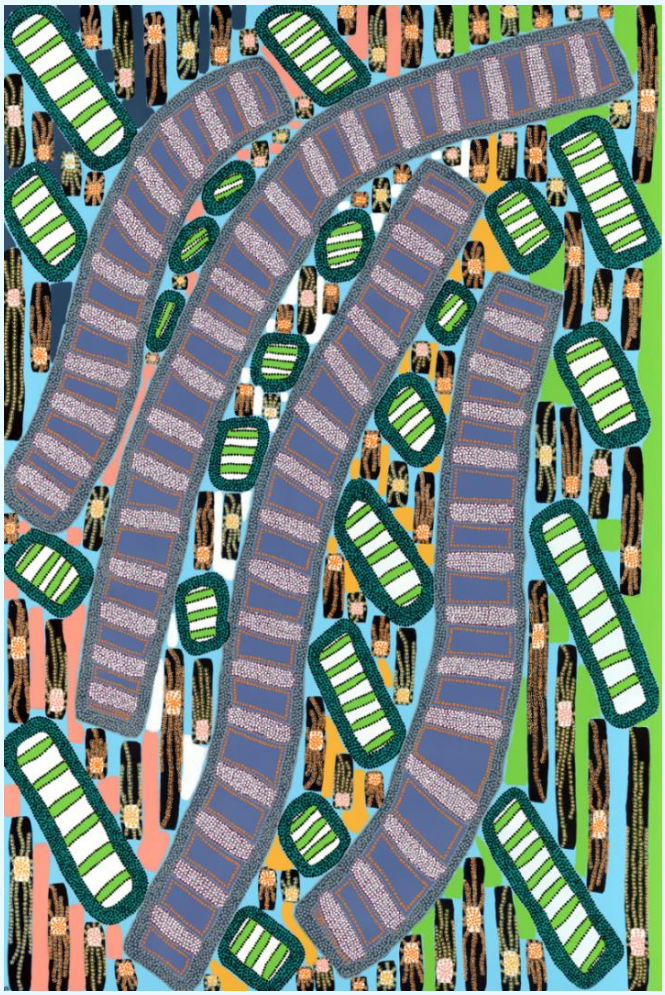
We pay respect to Elders past and present and commit to respecting the lands we walk on, and the communities we walk with.

We celebrate the deep and enduring connection of Aboriginal and Torres Strait Islander peoples to Country and acknowledge their continuing custodianship of the land, seas and sky.

We acknowledge the ongoing stewardship of Aboriginal and Torres Strait Islander peoples, and the important contribution they make to our communities and economies.

We reflect on the continuing impact of government policies and practices, and recognise our responsibility to work together with and for Aboriginal and Torres Strait Islander peoples, families and communities, towards improved economic, social and cultural outcomes.

Artwork:
Regeneration by Josie Rose



FACT SHEET: How to Calculate Embodied Carbon of a Concrete Mix

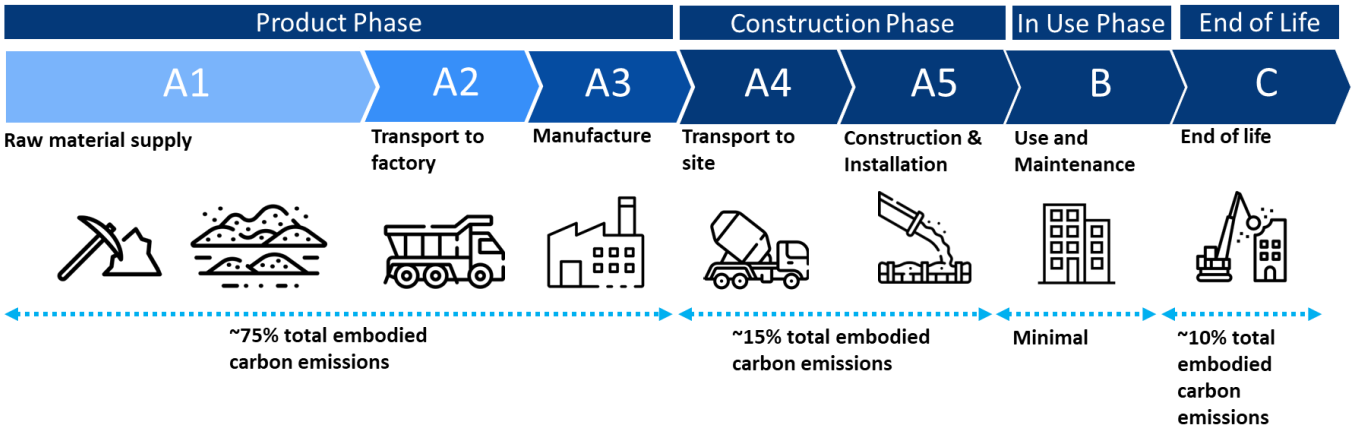
This fact sheet has been produced to enable the carbon impact of a concrete mix to be calculated. The scope covered by this calculation is the 'cradle to gate', i.e. product stage carbon (A1-A3). Note this fact sheet is intended to provide a simplified calculation to understand potential carbon reductions. Where possible it is encouraged, that data is obtained directly from the environmental product declaration (EPD) for the concrete mix. This will provide an accurate embodied carbon value for the concrete mix and is to be used in place of calculations nominated in this fact sheet if an EPD is available.

This fact sheet outlines the following:

- Introduction and background to concrete embodied carbon.
- Methodology for calculating the product stage carbon (A1-A3) of a concrete mix. This includes the impact of the cement, aggregate, water, any supplementary cementitious materials and admixtures.
- Carbon dataset that can be utilised for the calculation.
- Worked example for reference.

Background

Concrete is the most widely used construction material in the world and is responsible for 6-10% of global carbon dioxide (CO2) emissions. Portland cement is the primary constituent in concrete and is responsible for the majority of concrete's carbon emissions. The proportion of ingredients in a concrete mixture can greatly influence its carbon impact. The below diagram presents the approximate proportion of carbon associated with each of the life cycle stages. For further information on the impact of each stage see the IStructE Short guides to carbon factors by Arup here.



The global warming potential (referred to in this document as 'carbon') for concrete can vary depending on raw material extraction, processing and manufacturing techniques, supplementary cementitious materials, admixtures, transportation mode and distance, concrete strength requirements and use of water. Additionally, the source the data for the life cycle indicators (or carbon factors) will impact the overall carbon calculated for a concrete mix.

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Methodology

To calculate the carbon impact of a concrete mix the following approach is to be adopted:

1. Identify the quantities of each constituent in alignment with the concrete mix design.
2. Select the suitable carbon intensity factor that represents the constituent material from Table 1.
3. To obtain the equivalent carbon impact of each constituent multiply the quantity of each constituent (e.g. cement) with the carbon factor for that constituent (in this example the cement carbon factor). This will calculate the carbon impact of each constituent of the mix.
4. To obtain the carbon impact of the concrete mix add together the calculated carbon impact of each constituent from Step 3.

$$\begin{matrix}Carbon\ impact\ of \\ concrete\ mix \\ (kgCO2e/m3)\end{matrix} = \sum \begin{matrix}Quantity \\ of\ constituent \\ (kg/m3)\end{matrix} x \begin{matrix}Carbon\ emission \\ factor\ for\ constituent \\ (kgCO2e/kg)\end{matrix}$$

5. The carbon reduction between mixes can be calculated based on the comparison to a baseline concrete. The reduction is calculated as follows:

$$\begin{matrix}Carbon \\ reduction\ (\%)\end{matrix} = \left[1 - \left(\frac{Carbon\ impact\ of\ reduced\ carbon\ mix}{Carbon\ impact\ of\ baseline\ mix} \right) \right] x\ 100$$

A worked example is provided at the end of this fact sheet in Table 2 and Table 3 .

Carbon Dataset

Where Environmental Product Declarations (EPDs) are available for the concrete mix this is to be utilised to demonstrate the embodied carbon and carbon reduction. When EPDs are not available, the embodied carbon of concrete mix shall be calculated based on greenhouse gas intensity factors (also known as carbon factors or life cycle indicators).

This fact sheet uses the A1-A3 intensity factors sourced AusLCI (V1.42) Carbon Emissions Factors (Construction) presented in Table 1 (https://www.alcas.asn.au/auslci-emissions-factors). These factors are based on AusLCI and a shadow database that uses Ecoinvent data that is regionalised to Australia. Note, there are many different LCI databases globally and within Australia. For the assessment of carbon reductions on your project we recommend that the below table shall be used. Should a project wish to use more current data such as an EPD for cement to replace the below value this is allowed, where the value is less than that of the baseline set in Table 1.

Table 1: Intensity factors (Life cycle stages A1-A3) taken from Infrastructure Sustainability Materials Calculator V2.0.13 (LCI 2021)

Name	LCI Source	Global Warming Potential (kg CO2e/tonne)
Alkali activator (Sodium silicate)	AusLCI Shadow database	1099.1
Cement	AusLCI	966.9
Coarse Aggregates (Gravel, crushed)	AusLCI Shadow database	10.5
Fine Aggregates (Sand)	AusLCI Shadow database	4.2
Fly ash	AusLCI	19.8
GGBF slag	AusLCI	192.2
Mains water	AusLCI Shadow database	0.4
Manufactured sand (Gravel, crushed)	AusLCI	10.5
Recycled Aggregates	AusLCI	5.1

Worked Example

This example shows the carbon assessment of a 40 MPa 'baseline' mix compared against a 40MPa mix with a 45% carbon reduction target. The 40 MPa mix serves as an example to illustrate the calculation of embodied carbon. Note that the quantities used in this example are typical values for a 40 MPa mix and are not to be taken as a mix design for projects. Note the above global warming potential factors have been provided as a per kg, rather than tonne. This is to enable calculation of 1m3 of concrete.

Table 2: Example of embodied carbon of a baseline 40 MPa concrete mix

Mix Constituents		Quantity	Quantity Unit	Global Warming Potential Factor (kg CO2e/kg)	Total Global Warming Potential (kgCO2e/m^3)
Cement	OP cement	400	kg/m^3	0.97	386.76
Supplementary Cementitious Materials	Fly ash	-	kg/m^3	0.02	-
	GGBFS	-	kg/m^3	0.19	-
Coarse Aggregates	Coarse aggregate	1050	kg/m^3	0.011	11.01
	Recycled concrete aggregate (RCA)	-	kg/m^3	0.0051	-
Fine Aggregate	Fine aggregate	770	kg/m^3	0.0042	3.23
	Manufactured sand	-	kg/m^3	0.011	-
Admixtures	Superplasticiser	2.15	kg/m^3	2.2	4.73
Water	Mains Water	180	kg/m^3	0.0004	0.08
Carbon impact of baseline mix (kgCO2e/m^3)					**405.81**

Note the carbon impact of superplasticiser admixtures is not included within the AusLCI database therefore, based on a review of the academic papers and available EPDs a value of 2,200kgCO2e/kg[1] has been used. This factor may be substituted with information available from manufacturers when more accurate information is available. Information from suppliers to justify the selected carbon intensity factors for admixtures shall be provided to support the carbon reduction assessment.

Table 3: Example of embodied carbon of a 40 MPa concrete mix with a 45% emission reduction target compared to the baseline

Mix Constituents		Quantity	Quantity Unit	Global Warming Potential Factor (kg CO2e/kg)	Total Global Warming Potential (kgCO2e/m^3)
Cement	OP cement	160	kg/m^3	0.97	154.70
Supplementary Cementitious Materials	Fly ash	-	kg/m^3	0.02	-
	GGBFS	240	kg/m^3	0.19	46.13
Coarse Aggregates	Coarse aggregate	1050	kg/m^3	0.011	11.01
	Recycled concrete aggregate (RCA)	-	kg/m^3	0.0051	-
Fine Aggregate	Fine aggregate	770	kg/m^3	0.0042	3.23
	Manufactured sand	-	kg/m^3	0.011	-
Admixtures	Superplasticiser	2.15	kg/m^3	2.2	4.73

[1] M.A. DeRousseau, J.H. Arehart, J.R. Kasprzyk, W.V. Srubar, Statistical variation in the embodied carbon of concrete mixtures, Journal of Cleaner Production, 2020

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Mix Constituents		Quantity	Quantity Unit	Global Warming Potential Factor (kg CO2e/kg)	Total Global Warming Potential (kgCO2e/m^3)
Water	Mains Water	180	kg/m^3	0.0004	0.08
Carbon impact of reduced carbon mix (kgCO2e/m^3)					**219.89**
Carbon reduction compared to baseline concrete					**46%**

A template has been provided below for reference.

Table 4: Template for Mix Design Details and equivalent embodied carbon emission

Mix Constituents		Quantity	Quantity Unit	Global Warming Potential Factor (kg CO2e/kg)	Total Global Warming Potential (kgCO2e/m^3)
Cement	OP cement		kg/m^3	0.97	
Supplementary Cementitious Materials	Fly ash		kg/m^3	0.02	
	GGBFS		kg/m^3	0.19	
Coarse Aggregates	Coarse aggregate		kg/m^3	0.011	
	Recycled concrete aggregate (RCA)		kg/m^3	0.0051	
Fine Aggregate	Fine aggregate		kg/m^3	0.0042	
	Manufactured sand		kg/m^3	0.011	
Admixtures	Superplasticiser		kg/m^3	2.2*	
Water	Mains Water		kg/m^3	0.0004	
	Recycled/reused water		kg/m^3	0.00000	
Total mix embodied carbon (kgCO2e/m^3)					

* Consult manufacturer for factors or Table 1 for factor from literature

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