ICM Database

Integrated Carbon Metrics
Embodied Carbon Life Cycle Inventory Database

The Integrated Carbon Metrics (ICM) Embodied Carbon Life Cycle Inventory Database was created by the Sustainability Assessment Program at UNSW Sydney, supported by the CRC for Low Carbon Living (Project RP2007).

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Table of Contents

List of Abbreviations

ABS	Australian Bureau of Statistics
AGEIS	Australian Greenhouse Emissions Information System
ALCAS	Australian Life Cycle Assessment Society
AusLCI	Australian National Life Cycle Inventory
BOF	Basic Oxygen Furnace
CFI	Carbon Footprint Intensity
CH_4	Methane
CLT	Cross Laminated Timber
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CRCLCL	The Cooperative Research Centre for Low Carbon Living
CSP	Concentrated Solar Power
C^u	Upstream Cut-Off Matrix
EAF	Electric Arc Furnace
ECE	Embodied Carbon Explorer
EEIOA	Environmentally-extended Input-Output Analysis
EWPs	Engineered Wood Products
FA	Fly Ash
GGBFS	Ground Granulated Blast Furnace Slag
GHG	Greenhouse gas
GLT	Glued Laminated Timber
GPC	Geopolymer Concrete
GWP	Global Warming Potential
ICM	Integrated Carbon Metrics
IELab	Australian Industrial Ecology Virtual Laboratory
IOA	Input-Output Analysis
IOT	Input-Output Table
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LTE	Laminated Timber Element
N_2O	Nitrous Oxide
OPC	Ordinary Portland Cement
PV	Photovoltaic
SUT	Supply-and-Use Table

Chapter 1 Introduction

The Integrated Carbon Metrics (ICM) Embodied Carbon Life Cycle Inventory (LCI) Database ("ICM Database") provides Australian-specific Carbon Footprint Intensities for around 650 construction and building materials, as well as built environment-related products and processes (e.g. electricity production, transport, renewable energy installation, etc), based on a hybrid life cycle assessment methodology. Description of the scope, method and data sources are provided in a Q&A format in Chapter 2. The ICM Database is provided in Chapter 3. The CO_2e in Chapter 3 only takes into account CO_2, CH_4 and N_2O for both Hybrid and Process Carbon Footprint Intensities.

Detailed analysis and reliable quantification of embodied greenhouse gas emissions of buildings, precincts and infrastructure are a vital part of designing a low carbon built environment and achieving emissions reductions. The ICM database can be used to calculate embodied greenhouse gas emissions of construction materials, building products and processes in the construction and/or operational phase of buildings, precincts, infrastructures and other applications in the built environment. Including embodied greenhouse gas emissions in the life cycle calculations opens up a variety of additional solutions, such as identifying major contributors, finding less carbon-intense building materials and planning design structures.

The Integrated Carbon Metrics Embodied Carbon Life Cycle Inventory Database is an output of the Integrated Carbon Metrics project (number RP2007)[1] supported by the CRC for Low Carbon Living (CRCLCL)[2]. The ICM project developed metrics and decision support tools for building designers, manufacturers, planners and developers to support the successful implementation of low carbon initiatives.

[1] RP2007: http://www.lowcarbonlivingcrc.com.au/research/program-2-low-carbon-precincts/rp2007-integrated-carbon-metrics-%E2%80%93-multi-scale-life-cycle
RP2007u1: http://www.lowcarbonlivingcrc.com.au/research/program-2-low-carbon-precincts/rp2007u1-integrated-carbon-metrics-%E2%80%93-tool-alignment-national
[2] CRCLCL: http://www.lowcarbonlivingcrc.com.au/

Chapter 2 Questions about the ICM Database

2.1 What are embodied emissions?

Embodied emissions are the total amount of greenhouse gas (GHG) emissions emitted to manufacture a product or material. They include emissions from raw material extraction, manufacturing, processing, refining, transportation as well as services up to the final point of sale of the product or material. The system boundary is therefore Cradle-to-Point of Sale.

2.2 What are Carbon Footprint Intensities?

The Carbon Footprint Intensity (CFI) is the cumulative GHG emissions emitted that occurred in the entire supply chain network to produce and deliver one unit of the material under consideration. The Carbon Footprint Intensities (CFIs) are expressed as kg CO_2e per unit of material. Carbon dioxide equivalent (CO_2e) is a summation of GHG emissions weighted according to their global warming potential (GWP). In the case of the ICM Database, this includes carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

For example, the CFI of "Brick" is 0.302 kg CO_2e/kg (Refer to Hybrid CFI in Table 3). This means that 0.302 kg CO_2e of GHG emissions are emitted from extraction, manufacture, services and transportation to produce one kg of Brick to the point that the product is sold.

Carbon Footprint Intensities are also referred to as GHG emissions factors/coefficients/intensities, embodied carbon factors, input-output multipliers, total impact multipliers and Scope 3 multipliers.

2.3 What was the motivation to develop this database?

An initial scoping study (Fouché et al., 2015; Teh et al., 2019; Teh et al., 2015) has identified that there is a poor availability of Australian product-specific embodied GHG emissions data that constitutes a significant barrier to analyse and pursue low carbon options. To assist planners and architects in the quantification, software tools are being developed, but the inclusion of embodied GHG emissions in such tools is scant and still an emerging field. Embodied GHG emissions are also notoriously difficult to quantify, because supply chains are complex and many different processes and entities contribute to the total carbon load. (CRCLCL, 2019; Schinabeck and Wiedmann, 2014; Schinabeck et al., 2016; Wiedmann et al., 2017).

A comprehensive database of embodied carbon life cycle inventory data for Australian building products and construction materials is the fundamental component of the ICM project in an attempt to deliver an open source database for building designers,

manufacturers, planners and developers to help identify emission reduction opportunities in the Australian built environment.

2.4 What method is used to calculate the Carbon Footprint Intensities in this database?

Carbon Footprint Intensities are calculated using Hybrid Life Cycle Assessment (LCA) method. Hybrid LCA generally aims to combine the specificity of Life Cycle Assessment (LCA) with the comprehensiveness of Input-Output Analysis (IOA) by applying an economy-wide system boundary. There are several possibilities for this combination, but in all cases specific data on individual processes – most preferably process data – are connected with data from an input output model (Wiedmann, 2010). The type of hybrid LCA used for this database is integrated hybrid LCA, where the (monetary) input-output table is connected to a (physical) process matrix (Suh, 2004; Wiedmann, 2010). For more information, the different types of Hybrid LCA are described in detail in Crawford et al. (2018).

2.5 What data are used to calculate the Carbon Footprint Intensities in this database?

Two main types of data are hybridised in this database- **Process data** from the Australian National Life Cycle Inventory Database are connected with **Input-output data** from an Australian national Supply-and-Use Table (SUT). For more information, the integration of datasets and calculations are described in detail in Yu and Wiedmann (2018) and Yu et al. (2020).

- **Process Data**:
  The Australian National Life Cycle Inventory (AusLCI) Database which contains 4463 processes as well as GHG emissions data for— CO_2, CH_4 and N_2O are used (Grant, 2015). Characterisation factors for CH_4 and N_2O are retrieved from the Australian Greenhouse Emissions Information System (AGEIS) (AGEIS, 2017). The AusLCI is a major initiative currently being delivered by the Australian Life Cycle Assessment Society (ALCAS). The AusLCI dataset[3] is integrated with the ecoinvent dataset[4] version 2.2, where processes that are lacking in AusLCI are supplemented by ecoinvent, while processes that exists in AusLCI replace ecoinvent processes. AusLCI data are freely available to the public, whilst ecoinvent data are owned by ecoinvent requiring additional license for acquisition.

[3] AusLCI: http://www.auslci.com.au/index.php/datasets
[4] Ecoinvent: http://www.ecoinvent.org/

- **Input-Output Data:**
  The input-output data consist of a national Supply-and-Use Table with 1284 industries derived using detailed product information published by the Australian Bureau of Statistics (ABS) (ABS, 2018). The GHG emissions data for— CO_2, CH_4 and N_2O from the Australian Greenhouse Emissions Information System are utilised (AGEIS, 2017). Both the Input-output and GHG emission data are based on the data from 2014-2015. The input–output datasets employed are created with the Australian Industrial Ecology Virtual Laboratory (IELab)[5] with suitable IELab datafeed scripts (Geschke, 2017; Lenzen et al., 2017). IELab provides the possibility of creating detailed sub-national Multi-Region Input-Output Tables of the Australian economy with up to 2214 spatial areas and up to 1284 industries, depending on the research question and computational capacity (Lenzen et al., 2014; Wiedmann, 2017).

- **Price information of process data**:
  Price data are from ecoinvent that requires additional license for acquisition. The prices are in basic prices (in Australian dollars), which is exclusive of taxes and margins such as transport, retail or wholesale costs. Carbon Footprint Intensities in monetary unit basis (i.e. kg CO_2-e/$) are converted to physical unit basis (i.e. kg CO_2e/unit), based on these basic prices.

2.6 How are Carbon Footprint Intensities calculated after the integration of Process and Input-output data?

Using the Leontief inverse technique (Leontief, 1970), environmental impacts are allocated to consumer sectors with a set of input-output equations, capturing the total direct and indirect GHG emissions from processes across the supply chain from raw material extraction to the final product (Wiedmann and Minx, 2008). The Carbon Footprint Intensities derived from the Integrated Hybrid LCA method are expressed as kg CO_2e per unit of material, and are available in the ICM database as Hybrid CFIs and Process CFIs.

[5] IELab: https://ielab-aus.info/

2.7 What are Process CFIs and Hybrid CFIs?

Two types of Carbon Footprint Intensities are available in this database:

- **Hybrid CFIs**:
  Hybrid carbon footprint intensities include embodied GHG emissions calculated from AusLCI processes as well as input-output processes that are missing in the AusLCI processes (e.g. services, finance, insurance, machinery, equipment, capital, etc). CO_2e includes the GHG emissions of CO_2, CH_4 and N_2O.

- **Process CFIs**:
  Process carbon footprint intensities include embodied GHG emissions calculated from AusLCI processes or process data only (no embodied GHG emissions from input-output processes are included). CO_2e includes the GHG emissions of CO_2, CH_4 and N_2O.

2.8 How can the Process CFIs and Hybrid CFIs provided by the ICM Database be used to calculate embodied emissions?

CFIs (in kg CO_2e per unit of product) are multiplied by specific product quantities (e.g. tonnes of steel) to determine the total embodied GHG emissions of a product. We recommend using Hybrid CFIs since they have been shown to be more complete, to avoid truncation errors (Yu and Wiedmann, 2018). However, it is up to the user to decide using between Process and Hybrid CFIs for their analysis.

As an example, 50 m^3 of 25 MPa concrete are used in a construction of a new house. The Hybrid CFI for "25 MPa concrete" is 410 kg CO_2e/m^3 (Refer to Table 3).

Embodied greenhouse gas emissions of "25 MPa concrete" can be calculated as
= 50 m^3 x 410 kg CO_2e/m^3
= 20,500 kg CO_2e (20.5 t CO_2e)

This can be read as 20.5 t CO_2e of GHG emissions are emitted in total from the extraction, manufacturing, services and transportation processes from the 50 m^3 concrete used in the construction of the new house.

2.9 Are there any low carbon building materials and materials available in the ICM database?

The ICM Database in Table 3 consists of traditional/ conventional building materials and products. Newer products such as low-carbon building products may not be captured in the ICM Database (Input-output table as well as process database) because the market for these products is not well-established yet.

As part of the ICM project, several studies have also been carried out to calculate the CFIs of Australian-specific low-carbon building products and renewable energy technologies using the Hybrid LCA method (i.e. Input-output based Hybrid LCA, also known as Matrix Augmentation in Crawford (2008)). These studies are summarised below and the associated Hybrid CFIs are presented in Table 1Table 1:

- **Concrete Study**: The 'Ready-mixed concrete and mortar' sector was disaggregated into six types of concrete with varying degrees of Ordinary Portland Cement (OPC), fly ash (FA) and slag (GGBFS) as well as two types of geopolymer concrete (GPC) (Teh et al., 2017). The 'cement' sector was replaced with process data for OPC as part of this study (Teh et al., 2017).
- **Timber Study**: The 'Glued Laminated Lumber' sector was disaggregated into two types of Engineered Wood Products (EWPs), i.e. Glued Laminated Timber (GLT) manufacturing and Cross Laminated Timber (CLT) manufacturing (also labelled as Laminated Timber Element (LTE) manufacturing in the study) (Herlihy, 2015). Embodied carbon factors available only in monetary unit basis (i.e. kg CO_2-eq/AUD).
- **Steel Study**: 'Other steel and iron manufacturing' sector was disaggregated into two types of steel production, i.e. Basic Oxygen Furnace (BOF) steel manufacturing and Electric Arc Furnace (EAF) steel manufacturing (McIlvin, 2015). Embodied carbon factors available only in monetary unit basis (i.e. kg CO_2-eq/AUD).
- **Renewable Energy Study**: Three 'Electricity' sectors were disaggregated to 16 sub-sectors of energy technologies, which includes 'Geothermal', 'Concentrated Solar Power (CSP)', 'Solar Photovoltaic', 'Wind Onshore', 'Wind offshore', 'Hydro reservoir' and 'Hydro run-off' (Wolfram et al., 2016).

Table 1: CFIs of Australian-specific low-carbon building products and renewable energy technologies

Low-carbon building products/ Renewable energy technologies	Method	Hybrid Carbon Footprint Intensity (CFI)	Unit of CFI	Source
Geopolymer concrete 90% fly ash 50 MPa	Input-output based Hybrid LCA	345.46	kg CO_2e/m^3	(Teh et al., 2017)
Geopolymer concrete 90% slag 50 MPa	Input-output based Hybrid LCA	290.82	kg CO_2e/m^3	(Teh et al., 2017)
Electric Arc Furnace (EAF) Steel	Input-output based Hybrid LCA	0.72	kg CO_2e/AUD	(McIlvin, 2015)
Cross Laminated Timber (CLT)	Input-output based Hybrid LCA	0.42	kg CO_2e/AUD	(Herlihy, 2015)
Renewable Energy: Hydro run-off	Input-output based Hybrid LCA	37.2	g CO_2e/kWh	(Wolfram et al., 2016)
Renewable Energy: Hydro reservoir	Input-output based Hybrid LCA	48.5	g CO_2e/kWh	(Wolfram et al., 2016)
Renewable Energy: Wind onshore	Input-output based Hybrid LCA	43.4	g CO_2e/kWh	(Wolfram et al., 2016)
Renewable Energy: Wind offshore	Input-output based Hybrid LCA	45.1	g CO_2e/kWh	(Wolfram et al., 2016)
Renewable Energy: Solar Photovoltaic (PV)	Input-output based Hybrid LCA	73.3	g CO_2e/kWh	(Wolfram et al., 2016)
Renewable Energy: Concentrated Solar Power (CSP)	Input-output based Hybrid LCA	79.6	g CO_2e/kWh	(Wolfram et al., 2016)
Renewable Energy: Geothermal	Input-output based Hybrid LCA	92.2	g CO_2e/kWh	(Wolfram et al., 2016)

For more information on these studies, please refer to the sources listed in Table 1.

2.10 What is the difference between this database and other databases?

A number of databases exist, compiled for different geographic regions and using different methods. The values for identical products can vary substantially between databases, due to factors such as region-specific fuel mix and emissions intensity, analysis approach, data source, and process/system boundary coverage (Teh et al., 2019).

An important concept for measuring embodied emissions is the completeness as well as specificity of the analysis. This was addressed in the ICM database by utilising the hybrid LCA method and using Australian-specific data. The hybrid LCA method utilises an economy-wide system boundary which enables including a large number of processes and as a result provides a more comprehensive estimate than other methods. Australian-specific process and input-output data are used in this database to ensure that the CFI results reflect the actual embodied GHG emissions of a local product as closely as possible. For example, the CFIs are calculated using Australian-specific fuel mix in the production of the construction materials and building products. In a nutshell, ICM Database presents the embodied GHG emissions of country-specific construction materials and building products, whilst also maximising supply chain coverage.

2.11 How are these carbon footprint intensities different from the embodied carbon factors used in the Embodied Carbon Explorer (ECE) tool?

The Embodied Carbon Explorer (ECE) Tool[6] ("ECE Tool"), developed under the same project, is an online tool that calculates embodied (Scope 3) carbon emissions for a project at any level (e.g. precinct, building, organisation, material, etc.). Embodied carbon factors (equivalent to CFIs) utilised in the ECE tool are calculated using the Environmentally-extended Input-Output Analysis (EEIOA) (Leontief, 1970; Miller and Blair, 2009; Murray and Wood, 2010), which uses national Input-Output Tables (IOTs) published by ABS as the data source.

One of the main differences is in the sector resolution. For example, the ECE tool offers an embodied carbon factor for "Concrete" which consist of various concrete products (e.g. which includes concrete 20 MPa, concrete 32 MPa, concrete 40 MPa 30% fly ash, concrete 50 MPa 30% GGBFS and all other concrete types) whilst the ICM database offers specific concrete types such as "concrete 50 MPa 30% GGBFS". ECE tool has 344 product groups in total whilst the ICM Database has around 650 specific construction and building materials,

[6] ECE Tool: https://ece.ielab-aus.info/

as well as built environment-related products and processes (from 4463 sectors available in total).

The other differences of the ECE Tool and ICM Database are summarised in Table 2.

Table 2: Difference of method, data source, CFIs and results of the two ICM products- ECE Tool and ICM Database

	ECE Tool	**ICM Database**
What is the purpose of the tool/ database?	Calculates embodied GHG emissions of any project (e.g. precinct, building, organisation, material, etc.)	Provides CFIs of construction and building materials, as well as built environment-related products and processes
Which method is used in the tool/ database?	Environmentally-extended Input-Output Analysis	Integrated Hybrid Life Cycle Assessment
What is the data source of the tool/ database?	Australian Input-output data only	Australian Input-output data and Australian Process data
What is the data source of GHG emissions of the tool/ database?	AGEIS (2015)	AGEIS (2015) and AusLCI GHG emissions data
How many CFIs and for which products are these CFIs available for?	344 product groups in the whole economy	Around 650 construction materials, building products and processes, and built environment related products and processes
What is the unit of the CFIs in the tool/ database?	Monetary units (e.g. kg CO_2e/$)	Physical units (e.g. kg CO_2e/kg)
What is the unit of the results calculated from the tool/ database?	The CFIs (in kg CO_2e/$) available within the ECE Tool are used in the EEIOA calculation to produce results in **kt of CO_2e of the analysed project.**	The **CFIs, in kg CO_2e/physical unit** of specific building products are provided in the ICM Database. The CFIs are then used by the user to calculate the kg CO_2e of building products/ materials.

Chapter 3 ICM Database

The ICM Database in Table 3 provides Australian-specific Carbon Footprint Intensities for around 650 construction and building materials, as well as built environment-related products and processes (e.g. electricity production, transport, renewable energy installation, etc), based on a hybrid life cycle assessment method. An Excel spreadsheet version ("ICM Database") of Table 3 is also available for download. Explanation of the "Units" listed below can be found in the "Units" tab in the ICM Database Excel spreadsheet.

Table 3: Process CFIs and Hybrid CFIs of construction and building materials, as well as built environment-related products and processes

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
1	3kWp facade installation, multi-Si, laminated, integrated, at building	p	6,680	10,810
2	3kWp facade installation, multi-Si, panel, mounted, at building	p	7,020	10,770
3	3kWp facade installation, single-Si, laminated, integrated, at building	p	7,990	12,030
4	3kWp facade installation, single-Si, panel, mounted, at building	p	8,310	12,000
5	3kWp flat roof installation, multi-Si, on roof	p	7,130	10,870
6	3kWp flat roof installation, single-Si, on roof	p	8,410	12,090
7	3kWp slanted-roof installation, a-Si, laminated, integrated, on roof	p	5,830	8,910
8	3kWp slanted-roof installation, a-Si, panel, mounted, on roof	p	7,850	12,310
9	3kWp slanted-roof installation, CdTe, laminated, integrated, on roof	p	6,040	9,450
10	3kWp slanted-roof installation, CdTe, panel, mounted, on roof	p	7,440	11,660
11	3kWp slanted-roof installation, CIS, panel, mounted, on roof	p	7,860	11,040
12	3kWp slanted-roof installation, multi-Si, laminated, integrated, on roof	p	6,410	10,540
13	3kWp slanted-roof installation, multi-Si, panel, mounted, on roof	p	7,120	10,880
14	3kWp slanted-roof installation, ribbon-Si, laminated, integrated, on roof	p	6,250	7,990
15	3kWp slanted-roof installation, ribbon-Si, panel, mounted, on roof	p	7,020	9,590
16	3kWp slanted-roof installation, single-Si, laminated, integrated, on roof	p	7,740	11,780
17	3kWp slanted-roof installation, single-Si, panel,	p	8,400	12,100

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
	mounted, on roof			
18	Acrylic binder, 34% in H2O, at plant	kg	1.76	2.45
19	Adhesive mortar	kg	1.35	1.78
20	Alkyd paint, 60% in H2O	kg	2.96	4.18
21	Alkyd paint, 60% in solvent	kg	3.21	4.57
22	Aluminium alloy, AlMg3	kg	8.30	9.14
23	Aluminium product manufacturing, average metal working	kg	5.34	5.81
24	Aluminium scrap, new	kg	0.027	0.250
25	Aluminium scrap, old	kg	0.292	0.358
26	Aluminium	kg	20.5	22.0
27	Aluminium, primary, liquid	kg	20.3	21.7
28	Aluminium, production mix	kg	14.19	15.36
29	Aluminium, production mix, cast alloy	kg	4.88	5.48
30	Aluminium, production mix, wrought alloy	kg	18.45	19.90
31	Aluminium, secondary, from new scrap	kg	0.502	0.845
32	Aluminium, secondary, from old scrap	kg	1.68	1.97
33	Anhydrite floor	kg	0.0792	0.1230
34	Anhydrite rock	kg	0.0030	0.0044
35	Anhydrite	kg	0.0391	0.0541
36	Anhydrite, burned	kg	0.114	0.169
37	Argon	kg	0.596	0.753
38	Autoclaved aerated concrete block	kg	0.477	0.519
39	Bitumen sealing Alu80	kg	2.24	2.55
40	Bitumen sealing V60	kg	0.962	1.172
41	Bitumen sealing VA4	kg	1.73	2.03
42	Bitumen sealing	kg	1.25	1.51
43	Bitumen sealing, polymer EP4 flame retardant	kg	1.17	1.45
44	Bitumen, at refinery	kg	0.691	0.808
45	Black coal, average, at mine	kg	0.115	0.127
46	Black coal, NSW, at mine	kg	0.136	0.143
47	Black coal, QLD, at mine	kg	0.0970	0.1039
48	Black coal, WA, at mine	kg	0.0168	0.0227
49	Blast furnace slag cement	kg	0.587	0.665
50	Brick	kg	0.253	0.302
51	Building, hall, steel construction	m^2	422	520

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
52	Building, hall, wood construction	m^2	384	506
53	Building, hall	m^2	411	538
54	Building, multi-storey	m^3	285	365
55	Bulldozer operation, medium load factor	s	0.0281	0.0305
56	Cast iron, at plant	kg	1.71	2.11
57	Cellulose fibre	kg	0.556	0.840
58	Cement cast plaster floor	kg	0.199	0.222
59	Cement mortar	kg	0.240	0.273
60	Cement, unspecified	kg	0.959	1.017
61	Ceramic tiles	kg	0.961	1.167
62	Chromium steel 18/8	kg	4.82	5.58
63	Chromium steel product manufacturing, average metal working	kg	3.21	3.60
64	Chromium, at regional storage	kg	40.8	44.4
65	Cladding, crossbar-pole, aluminium	m^2	205	258
66	Clay plaster	kg	0.0457	0.0772
67	Clay, at mine	kg	0.0030	0.0178
68	Clinker	kg	0.982	1.008
69	Cold impact extrusion, aluminium, 1 stroke	kg	1.39	1.54
70	Cold impact extrusion, aluminium, 2 strokes	kg	2.06	2.27
71	Cold impact extrusion, aluminium	kg	2.72	3.01
72	Cold impact extrusion, aluminium, 4 strokes	kg	3.39	3.75
73	Cold impact extrusion, aluminium, 5 strokes	kg	4.05	4.48
74	Cold impact extrusion, steel, 1 stroke	kg	1.134	1.241
75	Cold impact extrusion, steel, 2 strokes	kg	1.33	1.46
76	Cold impact extrusion, steel	kg	1.52	1.67
77	Cold impact extrusion, steel, 4 strokes	kg	1.72	1.89
78	Cold impact extrusion, steel, 5 strokes	kg	1.91	2.11
79	Collection and processing of aluminium scrap	kg	0.115	0.139
80	Collection and processing of steel scrap	kg	0.285	0.307
81	Concrete 20 MPa 30% fly ash	m^3	236	281
82	Concrete 20 MPa 30% GGBFS	m^3	258	311
83	Concrete 20 MPa	m^3	321	369
84	Concrete 25 MPa 30% fly ash	m^3	267	314
85	Concrete 25 MPa 30% GGBFS	m^3	290	347
86	Concrete 25 MPa	m^3	359	410

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
87	Concrete 32 MPa 30% fly ash	m^3	304	354
88	Concrete 32 MPa 30% GGBFS	m^3	332	393
89	Concrete 32 MPa	m^3	412	467
90	Concrete 40 MPa 30% fly ash	m^3	365	418
91	Concrete 40 MPa 30% GGBFS	m^3	399	466
92	Concrete 40 MPa	m^3	496	556
93	Concrete 50 MPa 30% fly ash	m^3	464	527
94	Concrete 50 MPa 30% GGBFS	m^3	506	586
95	Concrete 50 MPa	m^3	628	698
96	Concrete block	kg	0.165	0.220
97	Concrete roof tile	kg	0.241	0.314
98	Concrete, exacting	m^3	412	494
99	Concrete, exacting, with de-icing salt contact	m^3	359	438
100	Concrete, normal	m^3	359	437
101	Concrete, sole plate and foundation	m^3	290	391
102	Connection piece, steel, 100x50 mm, at plant	p	1.18	1.38
103	Construction work, cogen unit 160kWe	p	4,600	6,310
104	Contour, brass	kg	0.570	0.728
105	Contour, bronze	kg	0.580	0.751
106	Copper product manufacturing, average metal working	kg	2.63	3.13
107	Copper telluride cement, from copper production	kg	0.724	1.130
108	Copper, at regional storage	kg	2.28	3.53
109	Copper, blister-copper, at primary smelter	kg	2.05	3.11
110	Copper, from combined metal production, at beneficiation	kg	1.05	1.36
111	Copper, from combined metal production, at refinery	kg	2.42	3.11
112	Copper, from imported concentrates, at refinery	kg	1.17	3.19
113	Copper	kg	4.04	5.39
114	Copper, primary, couple production nickel	kg	6.11	6.88
115	Copper, secondary, at refinery	kg	1.87	2.34
116	Copper, secondary, from electronic and electric scrap recycling, at refinery	kg	0.109	0.393
117	Copper, SX-EW, at refiner	kg	6.91	8.82
118	Core board, at plant	kg	1.066	1.352

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
119	Cork slab	kg	1.75	2.99
120	Corrugated board base paper, kraftliner	kg	1.21	1.57
121	Corrugated board base paper, semichemical fluting	kg	1.33	1.62
122	Corrugated board base paper, testliner	kg	0.845	1.074
123	Corrugated board base paper, wellenstoff	kg	0.842	1.068
124	Corrugated board, fresh fibre, single wall	kg	1.52	2.10
125	Corrugated board, fresh fibre, single wall	kg	1.47	2.03
126	Corrugated board, mixed fibre, single wall	kg	1.17	1.66
127	Corrugated board, mixed fibre, single wall	kg	1.15	1.64
128	Corrugated board, recycling fibre, double wall	kg	1.11	1.59
129	Corrugated board, recycling fibre, double wall	kg	1.10	1.58
130	Corrugated board, recycling fibre, single wall	kg	1.04	1.50
131	Corrugated board, recycling fibre, single wall	kg	1.04	1.49
132	Deep drawing, steel, 10000 kN press, automode operation	kg	0.376	0.416
133	Deep drawing, steel, 10000 kN press, single stroke operation	kg	0.608	0.673
134	Deep drawing, steel, 3500 kN press, automode operation	kg	0.374	0.414
135	Deep drawing, steel, 3500 kN press, single stroke operation	kg	0.467	0.517
136	Deep drawing, steel, 38000 kN press, automode operation	kg	0.377	0.417
137	Deep drawing, steel, 38000 kN press, single stroke operation	kg	0.664	0.735
138	Deep drawing, steel, 650 kN press, automode operation	kg	0.373	0.413
139	Deep drawing, steel, 650 kN press, single stroke operation	kg	0.411	0.455
140	Deformation stroke, cold impact extrusion, aluminium	kg	0.600	0.665
141	Deformation stroke, cold impact extrusion, steel	kg	0.131	0.145
142	Deformation stroke, hot impact extrusion, steel	kg	0.168	0.187
143	Deformation stroke, warm impact extrusion, steel	kg	0.170	0.188
144	Disposal, asphalt, 0.1% water, to sanitary landfill	kg	0.0207	0.0230
145	Disposal, bitumen sheet, 1.5% water, to	kg	2.35	2.36

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
	municipal incineration			
146	Disposal, bitumen, 1.4% water, to sanitary landfill	kg	0.134	0.136
147	Disposal, building wood, chrome preserved, 20% water, to municipal incineration	kg	0.0132	0.0148
148	Disposal, building, bitumen sheet, to final disposal	kg	2.35	2.36
149	Disposal, building, brick, to final disposal	kg	0.0137	0.0158
150	Disposal, building, brick, to recycling	kg	0.0034	0.0036
151	Disposal, building, brick, to sorting plant	kg	0.0173	0.0199
152	Disposal, building, bulk iron (excluding reinforcement), to sorting plant	kg	0.0056	0.0064
153	Disposal, building, cement-fibre slab, to final disposal	kg	0.0205	0.0233
154	Disposal, building, cement-fibre slab, to recycling	kg	0.0034	0.0036
155	Disposal, building, cement (in concrete) and mortar, to final disposal	kg	0.0145	0.0166
156	Disposal, building, cement (in concrete) and mortar, to sorting plant	kg	0.0252	0.0288
157	Disposal, building, concrete gravel, to final disposal	kg	0.0145	0.0166
158	Disposal, building, concrete gravel, to recycling	kg	0.0041	0.0044
159	Disposal, building, concrete gravel, to sorting plant	kg	0.0180	0.0205
160	Disposal, building, concrete, not reinforced, to final disposal	kg	0.0145	0.0166
161	Disposal, building, concrete, not reinforced, to recycling	kg	0.0041	0.0044
162	Disposal, building, concrete, not reinforced, to sorting plant	kg	0.0180	0.0205
163	Disposal, building, door, inner, glass-wood, to final disposal	m^2	10.39	11.12
164	Disposal, building, door, inner, wood, to final disposal	m^2	7.43	7.58
165	Disposal, building, door, outer, wood-aluminium, to final disposal	m^2	3.23	3.52
166	Disposal, building, door, outer, wood-glass, to final disposal	m^2	4.80	5.08
167	Disposal, building, electric wiring, to final disposal	kg	1.63	1.70
168	Disposal, building, emulsion paint on walls, to	kg	0.0103	0.0122

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
	final disposal			
169	Disposal, building, emulsion paint on walls, to sorting plant	kg	0.0528	0.0565
170	Disposal, building, emulsion paint on wood, to final disposal	kg	1.213	1.246
171	Disposal, building, emulsion paint remains, to final disposal	kg	2.78	2.94
172	Disposal, building, fibre board, to final disposal	kg	0.201	0.203
173	Disposal, building, glass pane (in burnable frame), to final disposal	kg	0.0269	0.0332
174	Disposal, building, glass pane (in burnable frame), to sorting plant	kg	0.0327	0.0400
175	Disposal, building, glass sheet, to final disposal	kg	0.0103	0.0122
176	Disposal, building, glass sheet, to sorting plant	kg	0.0138	0.0160
177	Disposal, building, glazing 2-IV, U<1.1W/m2K, LSG, to final disposal	m^2	5.04	5.12
178	Disposal, building, glazing 2-IV, U<1.1W/m2K, to final disposal	m^2	1.67	1.73
179	Disposal, building, glazing 3-IV, U<0.5W/m2K, to final disposal	m^2	2.52	2.61
180	Disposal, building, mineral plaster, to final disposal	kg	0.0103	0.0122
181	Disposal, building, mineral plaster, to sorting plant	kg	0.0211	0.0246
182	Disposal, building, mineral wool, to final disposal	kg	0.0103	0.0122
183	Disposal, building, mineral wool, to sorting plant	kg	0.0281	0.0440
184	Disposal, building, paint on metal, to final disposal	kg	0.0103	0.0122
185	Disposal, building, paint on metal, to sorting plant	kg	0.0063	0.0078
186	Disposal, building, paint on walls, to final disposal	kg	0.0103	0.0122
187	Disposal, building, paint on walls, to sorting plant	kg	0.0993	0.1031
188	Disposal, building, paint on wood, to final disposal	kg	2.39	2.39
189	Disposal, building, paint remains, to final disposal	kg	3.61	3.70
190	Disposal, building, PE sealing sheet, to final disposal	kg	2.55	2.56

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
191	Disposal, building, plaster-cardboard sandwich, to final disposal	kg	0.0137	0.0158
192	Disposal, building, plaster-cardboard sandwich, to recycling	kg	0.0034	0.0036
193	Disposal, building, plaster-cardboard sandwich, to sorting plant	kg	0.0301	0.0346
194	Disposal, building, plaster board, gypsum plaster, to final disposal	kg	0.0137	0.0158
195	Disposal, building, plaster board, gypsum plaster, to recycling	kg	0.0034	0.0036
196	Disposal, building, plaster board, gypsum plaster, to sorting plant	kg	0.0269	0.0310
197	Disposal, building, plastic plaster, to final disposal	kg	0.0103	0.0122
198	Disposal, building, plastic plaster, to sorting plant	kg	0.0244	0.0280
199	Disposal, building, polyethylene /polypropylene products, to final disposal	kg	3.00	3.00
200	Disposal, building, polystyrene isolation, flame-retardant, to final disposal	kg	3.15	3.16
201	Disposal, building, polyurethane foam, to final disposal	kg	2.50	2.51
202	Disposal, building, polyurethane sealing, to final disposal	kg	0.0103	0.0122
203	Disposal, building, polyurethane sealing, to sorting plant	kg	0.1065	0.1106
204	Disposal, building, polyvinylchloride products, to final disposal	kg	2.70	2.86
205	Disposal, building, PVC sealing sheet, to final disposal	kg	2.32	2.41
206	Disposal, building, reinforced concrete, to final disposal	kg	0.0161	0.0184
207	Disposal, building, reinforced concrete, to recycling	kg	0.0058	0.0062
208	Disposal, building, reinforced concrete, to sorting plant	kg	0.0194	0.0220
209	Disposal, building, reinforced plaster board, to final disposal	kg	0.0137	0.0158
210	Disposal, building, reinforced plaster board, to recycling	kg	0.0034	0.0036
211	Disposal, building, reinforced plaster board, to sorting plant	kg	0.254	0.258
212	Disposal, building, reinforcement steel, to final	kg	0.0696	0.0756

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
	disposal			
213	Disposal, building, reinforcement steel, to recycling	kg	0.0593	0.0635
214	Disposal, building, reinforcement steel, to sorting plant	kg	0.0664	0.0715
215	Disposal, building, vapour barrier, flame-retarded, to final disposal	kg	2.82	2.83
216	Disposal, building, waste wood, chrome preserved, to final disposal	kg	0.0150	0.0169
217	Disposal, building, waste wood, untreated, to final disposal	kg	0.0144	0.0163
218	Disposal, building, window frame, plastic, to final disposal	m^2	156	165
219	Disposal, building, window frame, wood-metal, to final disposal	m^2	25.5	25.8
220	Disposal, building, window frame, wood, to final disposal	m^2	19.33	19.62
221	Disposal, cement-fibre slab, 0% water, to municipal incineration	kg	0.0152	0.0175
222	Disposal, cement, hydrated, 0% water, to residual material landfill	kg	0.0105	0.0123
223	Disposal, concrete, 5% water, to inert material landfill	kg	0.0076	0.0089
224	Disposal, copper, 0% water, to municipal incineration	kg	0.0295	0.0363
225	Disposal, drilling waste, 71.5% water, to landfarming	kg	0.0014	0.0016
226	Disposal, drilling waste, 71.5% water, to residual material landfill	kg	0.0105	0.0123
227	Disposal, dust, alloyed EAF steel, 15.4% water, to residual material landfill/CH U/AusSD U	kg	0.410	0.438
228	Disposal, dust, unalloyed EAF steel, 15.4% water, to residual material landfill	kg	0.0105	0.0123
229	Disposal, emulsion paint remains, 0% water, to hazardous waste incineration	kg	2.77	2.92
230	Disposal, emulsion paint, 0% water, to inert material landfill	kg	0.0076	0.0089
231	Disposal, emulsion paint, 0% water, to municipal incineration	kg	1.211	1.243
232	Disposal, emulsion paint, 0% water, to sanitary landfill	kg	0.0529	0.0552
233	Disposal, exhaust air roof hood, steel, DN 400	p	0.0963	0.1103
234	Disposal, exhaust air valve, in-wall housing,	p	0.246	0.260

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
	plastic/steel, DN 125			
235	Disposal, flexible duct, aluminum/PET, DN of 125	m	0.267	0.268
236	Disposal, glass, 0% water, to inert material landfill	kg	0.0076	0.0089
237	Disposal, glass, 0% water, to municipal incineration	kg	0.0251	0.0311
238	Disposal, green liquor dregs, 25% water, to residual material landfill	kg	0.410	0.438
239	Disposal, gypsum, 19.4% water, to inert material landfill	kg	0.0076	0.0089
240	Disposal, gypsum, 19.4% water, to sanitary landfill	kg	0.0167	0.0193
241	Disposal, insulation spiral-seam duct, rockwool, DN 400, 30 mm	m	0.0546	0.0813
242	Disposal, limestone residue, 5% water, to inert material landfill	kg	0.0076	0.0089
243	Disposal, mineral wool, 0% water, to inert material landfill	kg	0.0076	0.0089
244	Disposal, packaging cardboard, 19.6% water, to inert material landfill	kg	0.0076	0.0089
245	Disposal, packaging cardboard, 19.6% water, to municipal incineration	kg	0.0331	0.0372
246	Disposal, packaging cardboard, 19.6% water, to sanitary landfill	kg	1.53	1.53
247	Disposal, packaging paper, 13.7% water, to municipal incineration	kg	0.0284	0.0313
248	Disposal, packaging paper, 13.7% water, to sanitary landfill	kg	1.193	1.196
249	Disposal, paint remains, 0% water, to hazardous waste incineration	kg	3.60	3.68
250	Disposal, paint, 0% water, to inert material landfill	kg	0.0076	0.0089
251	Disposal, paint, 0% water, to municipal incineration	kg	2.38	2.39
252	Disposal, paint, 0% water, to sanitary landfill	kg	0.1076	0.1100
253	Disposal, paper, 11.2% water, to municipal incineration	kg	0.0277	0.0305
254	Disposal, paper, 11.2% water, to sanitary landfill	kg	1.194	1.198
255	Disposal, PE sealing sheet, 4% water, to municipal incineration	kg	2.55	2.55
256	Disposal, plastic plaster, 0% water, to inert	kg	0.0076	0.0089

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
	material landfill			
257	Disposal, plastic plaster, 0% water, to sanitary landfill	kg	0.0180	0.0204
258	Disposal, plastics, mixture, 15.3% water, to municipal incineration	kg	2.37	2.37
259	Disposal, plastics, mixture, 15.3% water, to sanitary landfill	kg	0.1059	0.1083
260	Disposal, pollutants from rail ballast, 0% water, to residual material landfill	kg	0.410	0.438
261	Disposal, polyethylene terephtalate, 0.2% water, to municipal incineration/	kg	2.03	2.04
262	Disposal, polyethylene terephtalate, 0.2% water, to sanitary landfill	kg	0.0947	0.0971
263	Disposal, polyethylene, 0.4% water, to municipal incineration	kg	3.00	3.00
264	Disposal, polyethylene, 0.4% water, to sanitary landfill	kg	0.132	0.135
265	Disposal, polypropylene, 15.9% water, to municipal incineration	kg	2.54	2.54
266	Disposal, polypropylene, 15.9% water, to sanitary landfill	kg	0.1138	0.1161
267	Disposal, polystyrene, 0.2% water, to municipal incineration	kg	3.17	3.17
268	Disposal, polystyrene, 0.2% water, to sanitary landfill	kg	0.139	0.141
269	Disposal, polyurethane, 0.2% water, to inert material landfill	kg	0.0076	0.0089
270	Disposal, polyurethane, 0.2% water, to municipal incineration	kg	2.50	2.51
271	Disposal, polyurethane, 0.2% water, to sanitary landfill	kg	0.1146	0.1174
272	Disposal, polyvinylchloride, 0.2% water, to municipal incineration	kg	2.70	2.86
273	Disposal, polyvinylchloride, 0.2% water, to sanitary landfill	kg	0.0775	0.0799
274	Disposal, polyvinylfluoride, 0.2% water, to municipal incineration	kg	2.25	2.27
275	Disposal, PVC sealing sheet, 1.64% water, to municipal incineration	kg	2.32	2.41
276	Disposal, railway track	my	7.18	8.40
277	Disposal, road	my	0.105	0.154
278	Disposal, rubber, unspecified, 0% water, to municipal incineration	kg	3.16	3.17

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
279	Disposal, steel, 0% water, to inert material landfill	kg	0.0076	0.0089
280	Disposal, steel, 0% water, to municipal incineration	kg	0.0176	0.0224
281	Disposal, tram track	my	0.995	1.165
282	Disposal, tram	p	2,220	2,230
283	Disposal, vapour barrier, flame-retarded, 4.5% water, to municipal incineration	kg	2.82	2.83
284	Disposal, waste, Si wafer production, 9.4% water, to residual material landfill	kg	0.410	0.438
285	Disposal, waste, silicon wafer production, 0% water, to underground deposit	kg	0.0840	0.1044
286	Disposal, wire plastic, 3.55% water, to municipal incineration	kg	2.64	2.74
287	Disposal, wood ash mixture, pure, 0% water, to landfarming	kg	0.0014	0.0016
288	Disposal, wood ash mixture, pure, 0% water, to municipal incineration	kg	0.0230	0.0286
289	Disposal, wood ash mixture, pure, 0% water, to sanitary landfill	kg	0.0220	0.0245
290	Disposal, wood pole, chrome preserved, 20% water, to municipal incineration	kg	0.0139	0.0156
291	Disposal, wood untreated, 20% water, to municipal incineration	kg	0.0126	0.0141
292	Disposal, wood untreated, 20% water, to sanitary landfill	kg	0.0788	0.0812
293	Door, inner, glass-wood	m^2	69.6	108.0
294	Door, inner, wood	m^2	55.2	83.6
295	Door, outer, wood-aluminium	m^2	125	165
296	Door, outer, wood-glass	m^2	123	168
297	Drawing of pipes, steel	kg	0.531	0.576
298	Elbow 90°, steel, 100x50 mm	p	1.61	1.89
299	Electric installation, photovoltaic plant, at plant	p	151	184
300	Electricity, high voltage, Australian	MJ	0.269	0.277
301	Electricity, high voltage, coal Australian average	MJ	0.328	0.338
302	Electricity, high voltage, Eastern Australian	MJ	0.271	0.280
303	Electricity, high voltage, New South Wales	MJ	0.283	0.291
304	Electricity, high voltage, Northern Territory	MJ	0.200	0.204
305	Electricity, high voltage, Queensland	MJ	0.255	0.261

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
306	Electricity, high voltage, South Australia	MJ	0.189	0.196
307	Electricity, high voltage, Tasmania	MJ	0.0578	0.0618
308	Electricity, high voltage, Victoria	MJ	0.347	0.360
309	Electricity, high voltage, Western Australia	MJ	0.221	0.226
310	Electricity, low voltage, Australian	MJ	0.283	0.303
311	Electricity, low voltage, coal Australian average	MJ	0.346	0.367
312	Electricity, low voltage, New South Wales	MJ	0.296	0.315
313	Electricity, low voltage, Northern Territory	MJ	0.213	0.229
314	Electricity, low voltage, Queensland	MJ	0.269	0.287
315	Electricity, low voltage, South Australia	MJ	0.201	0.221
316	Electricity, low voltage, Tasmania	MJ	0.0619	0.0774
317	Electricity, low voltage, Victoria	MJ	0.369	0.394
318	Electricity, low voltage, Western Australia/AU U	MJ	0.235	0.252
319	Electricity, PV, at 3kWp slanted-roof, CdTe, panel, mounted	MJ	0.0250	0.0394
320	Electricity, PV, at 3kWp slanted-roof, multi-Si, panel, mounted	MJ	0.0238	0.0367
321	Energy reduction, ventilation system, 1 x 720 m3/h, PE ducts, with GHE/	MJ	0.1101	0.1195
322	Energy reduction, ventilation system, 1 x 720 m3/h, steel ducts, with GHE	MJ	0.114	0.124
323	Energy reduction, ventilation system, 6 x 120 m3/h, PE ducts, with GHE	MJ	0.115	0.125
324	Energy reduction, ventilation system, 6 x 120 m3/h, PE ducts, without GHE	MJ	0.132	0.143
325	Energy reduction, ventilation system, 6 x 120 m3/h, steel ducts, with GHE	MJ	0.119	0.130
326	Energy reduction, ventilation system, 6 x 120 m3/h, steel ducts, without GHE	MJ	0.136	0.151
327	Excavation, hydraulic digger	m^3	0.553	1.151
328	Excavation, skid-steer loader	m^3	0.534	1.129
329	Exhaust air outlet, steel/aluminum, 85x365 mm, at plant	p	19.1	21.8
330	Exhaust air roof hood, steel, DN 400, at plant	p	60.5	72.4
331	Exhaust air valve, in-wall housing, plastic/steel, DN 125	p	2.31	2.76
332	Expanded clay	kg	0.358	0.469
333	Extrusion, plastic film	kg	0.858	0.940
334	Extrusion, plastic pipes	kg	0.635	0.697

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
335	Facade construction, integrated, at building	m^2	72.4	78.9
336	Facade construction, integrated, at building	m^2	66.8	72.8
337	Facade construction, integrated, on roof	p	1,480	3,160
338	Facade construction, mounted, at building	m^2	54.5	60.0
339	Facade construction, mounted, at building	m^2	58.2	64.1
340	Facade construction, mounted, on roof	p	1,540	3,240
341	Fibre cement corrugated slab	kg	1.069	1.182
342	Fibre cement facing tile	kg	1.44	1.73
343	Fibre cement facing tile, large format	kg	1.45	1.68
344	Fibre cement facing tile, small format	kg	1.42	1.63
345	Fibre cement roof slate	kg	1.12	1.49
346	Fibreboard hard, at plant	m^3	806	1,012
347	Fibreboard soft, at plant (u=7%)	m^3	130	175
348	Fibreboard soft, at plant	m^3	271	345
349	Fibreboard soft, latex bonded, at plant (u=7%)	m^3	224	281
350	Fibreboard soft, without adhesives, at plant (u=7%)	m^3	197	250
351	Flat glass, coated	kg	1.21	1.78
352	Flat glass, uncoated	kg	1.05	1.58
353	Flat plate collector, at plant	m^2	145	507
354	Flat roof construction, on roof	m^2	78.4	85.0
355	Flat roof construction, on roof	p	3,360	5,390
356	Flat roof construction, on roof	m^2	60.1	65.3
357	Flexible duct, aluminum/PET, DN of 125	m	1.48	3.21
358	Fly ash, delivered to plant	kg	0.0190	0.0269
359	Foam glass	kg	2.56	2.99
360	Foaming, expanding	kg	1.088	1.158
361	Fodder loading, by self-loading trailer	m^3	0.743	0.818
362	General purpose cement	kg	0.925	0.960
363	General purpose cement, Australian average	kg	0.959	1.009
364	General purpose cement, imported clinker	kg	1.068	1.166
365	Glass cullets, sorted, at sorting plant	kg	0.0582	0.0838
366	Glass fibre reinforced plastic, polyamide, injection moulding	kg	9.72	10.35
367	Glass fibre reinforced plastic, polyester resin, hand lay-up	kg	5.97	7.26
368	Glass fibre	kg	3.45	3.94

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
369	Glass tube, borosilicate	kg	2.98	4.18
370	Glass wool mat	kg	3.63	4.23
371	Glass, from public collection, unsorted	kg	0.0374	0.0444
372	Glazing, double (2-IV), U<1.1 W/m2K	m^2	36.7	56.4
373	Glazing, double (2-IV), U<1.1 W/m2K, laminated safety glass	m^2	54.7	88.1
374	Glazing, triple (3-IV), U<0.5 W/m2K	m^2	74.2	105.5
375	Glued laminated timber, indoor use	m^3	379	680
376	Glued laminated timber, outdoor use	m^3	400	706
377	Gravel, crushed	kg	0.0129	0.0149
378	Gravel, round	kg	0.0050	0.0061
379	Gravel, unspecified	kg	0.0067	0.0087
380	Ground granulated blast furnace slag, at cement plant	kg	0.215	0.301
381	Gypsum fibre board	kg	0.345	0.707
382	Gypsum plaster board	kg	0.432	0.523
383	Gypsum, mineral	kg	0.0030	0.0044
384	Hardwood poles	m^3	378	524
385	Hardwood pulp log, low quality	m^3	49.9	96.5
386	Hardwood sawlog, high quality	m^3	138	197
387	Hardwood sawlog, low quality	m^3	57.4	93.7
388	Hardwood timber production	m^3	75.6	106.2
389	Hardwood veneer log	m^3	212	297
390	Hardwood, stand establishment / tending / site development, under bark	m^3	4.60	21.48
391	Hot impact extrusion, steel, 1 stroke	kg	1.76	1.95
392	Hot impact extrusion, steel, 2 strokes	kg	1.99	2.20
393	Hot impact extrusion, steel	kg	2.22	2.46
394	Hot impact extrusion, steel, 4 strokes	kg	2.45	2.72
395	Hot impact extrusion, steel, 5 strokes	kg	2.69	2.98
396	Hot rolling, steel	kg	0.346	0.384
397	Hot water tank 600l	p	790	966
398	Iron ore, 46% Fe, at min	kg	0.0057	0.0215
399	Iron ore, 65% Fe, at beneficiation	kg	0.0286	0.0741
400	Iron scrap, at plant	kg	0.0548	0.0918
401	Laminated timber element, transversally prestressed, for outdoor use	m^3	310	619

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
402	Light clay brick	kg	0.153	0.196
403	Light mortar	kg	0.539	0.639
404	Lightweight concrete block, expanded clay	kg	0.448	0.614
405	Lightweight concrete block, expanded perlite	kg	1.10	1.61
406	Lightweight concrete block, expanded vermiculite	kg	0.374	0.458
407	Lightweight concrete block, polystyrene	kg	1.28	1.38
408	Lightweight concrete block, pumice	kg	0.252	0.296
409	Lime mortar	kg	0.696	0.848
410	Limestone	kg	0.0020	0.0049
411	Limestone, crushed, for mill	kg	0.0025	0.0081
412	Limestone, crushed, washed	kg	0.0026	0.0082
413	Limestone, milled, loose	kg	0.0281	0.0593
414	Limestone, milled, packed	kg	0.0393	0.0972
415	Logs, hardwood, at forest	m^3	138	205
416	Logs, mixed, at forest	m^3	138	205
417	Logs, softwood, at forest	m^3	41.0	75.3
418	Mastic asphalt	kg	0.253	0.301
419	Medium density fibreboard	m^3	699	877
420	Melamine	kg	5.42	6.42
421	Metal product manufacturing	kg	2.67	3.00
422	Milling, aluminium, average	kg	16.54	17.96
423	Milling, aluminium, dressing	kg	23.1	25.2
424	Milling, aluminium, large parts	kg	16.31	17.71
425	Milling, aluminium, small parts	kg	18.06	19.64
426	Milling, cast iron, average	kg	3.82	4.45
427	Milling, cast iron, dressing	kg	6.54	7.46
428	Milling, cast iron, large parts	kg	3.73	4.34
429	Milling, cast iron, small parts	kg	4.46	5.15
430	Milling, chromium steel, average	kg	7.53	8.58
431	Milling, chromium steel, dressing	kg	19.9	22.2
432	Milling, chromium steel, large parts	kg	7.10	8.11
433	Milling, chromium steel, small parts	kg	10.40	11.76
434	Milling, steel, average	kg	4.40	5.06
435	Milling, steel, dressing	kg	13.11	14.71
436	Milling, steel, large parts	kg	4.10	4.73

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
437	Milling, steel, small parts	kg	6.43	7.31
438	Multi-Si wafer, at plant	m^2	110.3	142.7
439	Multi-Si wafer, ribbon, at plant	m^2	81.5	98.3
440	Natural rubber based sealing	kg	2.31	3.22
441	Nylon 66	kg	8.29	8.53
442	Nylon 66, glass-filled	kg	7.22	7.45
443	Ordinary portland cement	kg	0.974	1.011
444	Ordinary portland cement, Australian average	kg	1.009	1.061
445	Ordinary portland cement, imported clinker	kg	1.126	1.230
446	Oriented strand board	m^3	434	654
447	Packaging film, LDPE	kg	3.14	3.78
448	Packaging glass, brown	kg	0.687	0.805
449	Packaging glass, brown	kg	1.057	1.199
450	Packaging glass, green	kg	0.631	0.746
451	Packaging glass, green	kg	1.033	1.169
452	Packaging glass, white	kg	0.705	0.823
453	Packaging glass, white	kg	1.050	1.190
454	Packaging, corrugated board, mixed fibre, single wall	kg	1.61	2.51
455	Packaging, corrugated board, mixed fibre, single wall	kg	1.42	2.27
456	Packing, cement	kg	0.0046	0.0061
457	Packing, clay products	kg	0.0077	0.0094
458	Packing, fibre cement products	kg	0.0205	0.0251
459	Packing, lime products	kg	0.0111	0.0141
460	Particle board, indoor use	m^3	337	465
461	Particle board, outdoor use	m^3	438	574
462	Pc-Si wafer, at plant	p	1.43	5.23
463	Photovoltaic cell, mc-Si, at plan	p	4.98	9.49
464	Photovoltaic cell, multi-Si, at plant	m^2	155	198
465	Photovoltaic cell, pc-Si , at plant	p	1.83	6.05
466	Photovoltaic cell, ribbon-Si, at plant	m^2	125.3	151.3
467	Photovoltaic cell, single-Si, at plant	m^2	235	286
468	Photovoltaic laminate, a-Si, at plant	m^2	50.3	77.5
469	Photovoltaic laminate, CdTe, mix, at regional storage	m^2	91.8	158.8
470	Photovoltaic laminate, CIS, at plant	m^2	162	212

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
471	Photovoltaic laminate, mc-Si, at plan	p	603	1,126
472	Photovoltaic laminate, multi-Si, at plant	m^2	181	284
473	Photovoltaic laminate, pc-Si, at plant	p	248	738
474	Photovoltaic laminate, ribbon-Si, at plant	m^2	154	199
475	Photovoltaic laminate, single-Si, at plant	m^2	256	366
476	Photovoltaic panel, a-Si, at plant	m^2	83.5	137.7
477	Photovoltaic panel, CdTe, mix, at plant	m^2	89.4	158.7
478	Photovoltaic panel, CIS, at plant	m^2	177	248
479	Photovoltaic panel, mc-Si, at plant	p	625	1,151
480	Photovoltaic panel, multi-Si, at plant	m^2	203	300
481	Photovoltaic panel, pc-Si, at plant	p	271	763
482	Photovoltaic panel, ribbon-Si, at plant	m^2	176	236
483	Photovoltaic panel, single-Si, at plant	m^2	278	382
484	Pipeline, crude oil, offshor	m	1,320	1,640
485	Pipeline, crude oil, onshore	m	588	711
486	Pipeline, natural gas, high pressure distribution network	m	89.0	134.1
487	Pipeline, natural gas, high pressure distribution network	m	72.4	113.4
488	Pipeline, natural gas, long distance, high capacity, offshore	m	1,700	2,210
489	Pipeline, natural gas, long distance, high capacity, onshore	m	1,220	1,520
490	Pipeline, natural gas, long distance, low capacity, onshore	m	918	1,120
491	Pipeline, natural gas, low pressure distribution network	m	80.2	99.5
492	Plaster mixing	kg	0.0821	0.0881
493	Plaster	kg	0.201	0.236
494	Plasterboard 10 mm	m^2	4.93	9.35
495	Plasterboard, 10mm	m^2	4.71	8.74
496	Plastic mulch, 25micron	m^2	0.0724	0.0789
497	Plywood, indoor use	m^3	1,040	1,370
498	Plywood, outdoor use	m^3	1,200	1,570
499	Polybutadiene	kg	4.00	4.20
500	Polyethylene, HDPE, granulate	kg	2.01	2.12
501	Polyethylene, LDPE, granulate	kg	2.19	2.38
502	Polyethylene, LLDPE, granulate	kg	1.93	2.12

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
503	Polypropylene	kg	2.27	2.50
504	Polystyrene foam slab, 100% recycled	kg	0.877	1.360
505	Polystyrene foam slab, 45% recycled	kg	2.76	3.23
506	Polystyrene foam slab	kg	4.78	5.24
507	Polyurethane, rigid foam	kg	4.73	5.22
508	Polyvinylchloride	kg	2.04	2.46
509	Portland calcareous cement	kg	0.860	0.914
510	Portland cement, strength class Z 42.5	kg	0.925	0.968
511	Portland cement, strength class Z 52.5	kg	0.925	0.968
512	Portland slag sand cement	kg	0.850	0.918
513	Powder coating, aluminium sheet	m^2	4.58	5.08
514	Powder coating, steel	m^2	5.49	6.12
515	Production of carton board boxes, gravure printing	kg	0.897	1.012
516	Production of carton board boxes, offset printing	kg	0.687	0.791
517	Quicklime, in pieces, loose, at plant	kg	1.028	1.065
518	Quicklime, milled, loose, at plant	kg	1.042	1.093
519	Quicklime, milled, packed, at plant	kg	1.053	1.120
520	Recycled aggregate	kg	0.0056	0.0119
521	Recycled steel from concrete recycling, at plant	kg	0.0293	0.1233
522	Recycling aluminium	kg	19.54	21.06
523	Recycling brick rubble and concrete	kg	0.0064	0.0091
524	Recycling steel	kg	1.71	2.11
525	Reinforcing steel	kg	1.63	2.01
526	Roof tile	kg	0.388	0.453
527	Round wood, hardwood, under bark, u=70%, at forest road	m^3	138	205
528	Round wood, primary forest, clear-cutting, at forest road	m^3	8.32	19.71
529	Round wood, primary forest, clear-cutting, at forest road	m^3	8.32	19.71
530	Round wood, Scandinavian softwood, under bark, u=70% at forest road	m^3	41.0	75.3
531	Round wood, softwood, debarked, u=70% at forest road	m^3	43.2	84.1
532	Round wood, softwood, under bark, u=70% at forest road	m^3	41.0	75.3

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
533	Roundwood, azobe (SFM), debarked, u=30%, CM, at maritime harbour	m^3	271	434
534	Roundwood, azobe (SFM), under bark, u=30%, at forest road	m^3	106	164
535	Roundwood, eucalyptus ssp. (SFM), under bark, u=50%, at forest road	m^3	49.9	109.5
536	Roundwood, meranti (SFM), debarked, u=70%	m^3	292	514
537	Roundwood, meranti (SFM), under bark, u=70%, at forest road	m^3	61.2	129.2
538	Roundwood, paraná pine (SFM), under bark, u=50%, at forest road	m^3	193	245
539	Sand-lime brick	kg	0.150	0.401
540	Sand	kg	0.0050	0.0062
541	Sanitary ceramics	kg	2.71	3.61
542	Sawn timber (SFM), azobe, planed, air dried, u=15%	m^3	524	793
543	Sawn timber, hardwood, planed, air / kiln dried, u=10%	m^3	395	757
544	Sawn timber, hardwood, planed, kiln dried, u=10%	m^3	430	745
545	Sawn timber, hardwood, raw, air / kiln dried, u=10%	m^3	315	582
546	Sawn timber, hardwood, raw, air dried, u=20%	m^3	300	516
547	Sawn timber, hardwood, raw, kiln dried, u=10%	m^3	345	570
548	Sawn timber, hardwood, raw, plant-debarked, u=70%	m^3	263	412
549	Sawn timber, paraná pine (SFM), kiln dried, u=15%	m^3	687	849
550	Sawn timber, paraná pine (SFM), u=15%	m^3	799	1,040
551	Sawn timber, Scandinavian softwood, raw, plant-debarked, u=70%	m^3	175	277
552	Sawn timber, softwood, planed, air dried	m^3	182	396
553	Sawn timber, softwood, planed, kiln dried	m^3	220	443
554	Sawn timber, softwood, raw, air dried, u=20%	m^3	128	282
555	Sawn timber, softwood, raw, forest-debarked, u=70%	m^3	116	231
556	Sawn timber, softwood, raw, kiln dried, u=10%	m^3	161	323
557	Sawn timber, softwood, raw, kiln dried, u=20%	m^3	150	309
558	Sawn timber, softwood, raw, plant-debarked, u=70%	m^3	114	198

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
559	Section bar extrusion, aluminium	kg	1.69	1.83
560	Section bar rolling, steel	kg	0.241	0.262
561	Selective coating, aluminium sheet, nickel pigmented aluminium oxide	m^2	6.33	7.16
562	Selective coating, copper sheet, black chrome	m^2	3.51	3.89
563	Selective coating, copper sheet, black majic	m^2	1.85	2.17
564	Selective coating, copper sheet, physical vapour deposition	m^2	1.30	1.42
565	Selective coating, copper sheet, sputtering	m^2	4.41	4.88
566	Selective coating, stainless steel sheet, black chrome	m^2	2.01	2.25
567	Sheet rolling, aluminium	kg	0.965	1.037
568	Sheet rolling, chromium steel	kg	0.819	0.910
569	Sheet rolling, copper	kg	0.481	0.560
570	Sheet rolling, steel	kg	0.469	0.526
571	Silicon, production mix, photovoltaics, at plant	kg	45.1	59.2
572	Silicon, solar grade, modified Siemens process, at plant	kg	39.6	46.3
573	Single-Si wafer, photovoltaics, at plant	m^2	186	225
574	Single cell, lithium-ion battery, lithium manganese oxide/graphite, at plant	kg	7.23	11.29
575	Slanted-roof construction, integrated, on roof	m^2	52.4	57.7
576	Slanted-roof construction, integrated, on roof	p	2,080	2,610
577	Slanted-roof construction, integrated, on roof	m^2	55.2	60.7
578	Slanted-roof construction, mounted, on roof	m^2	56.3	62.1
579	Slanted-roof construction, mounted, on roof	p	1,260	2,310
580	Slanted-roof construction, mounted, on roof	m^2	62.4	68.7
581	Softwood pole	m^3	24.2	53.3
582	Softwood pulp log	m^3	11.8	42.0
583	Softwood sawlog, high quality	m^3	41.0	67.8
584	Softwood sawlog, low quality	m^3	29.1	52.3
585	Softwood timber production	m^3	28.7	44.4
586	Softwood, stand establishment / tending / site development, under bark	m^3	2.07	16.73
587	Softwood, woodchips	m^3	27.9	48.4
588	Solar collector glass tube, with silver mirror, at plant	kg	10.23	12.59
589	Solar glass, low-iron, at regional storage	kg	1.19	2.22

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
590	Solar system with evacuated tube collector, one-family house, combined system	p	3,020	6,100
591	Solar system, flat plate collector, multiple dwelling, hot water	p	14,600	58,400
592	Solar system, flat plate collector, one-family house, combined system	p	3,810	18,700
593	Solar system, flat plate collector, one-family house, hot water	p	1,760	7,750
594	Steel product manufacturing, average metal working	kg	2.55	2.85
595	Steel, converter, chromium steel 18/8	kg	4.61	5.34
596	Steel, converter, low-alloyed	kg	2.10	2.52
597	Steel, converter, unalloyed	kg	1.64	2.00
598	Steel, electric, chromium steel 18/8	kg	4.23	4.86
599	Steel, electric, un- and low-alloyed	kg	0.667	0.808
600	Steel, low-alloyed	kg	1.92	2.31
601	Stucco	kg	0.0956	0.1158
602	Synthetic rubber	kg	3.42	4.13
603	Tempering, flat glass	kg	0.244	0.321
604	Thermal plaster, at plant	kg	0.887	1.079
605	Thermoforming, with calendering	kg	1.31	1.43
606	Three layered laminated board, at plant/RER U/AusSD U	m^3	555	1,046
607	Transport, lorry >16t, fleet average	tkm	0.184	0.216
608	Transport, lorry >28t, fleet average	tkm	0.107	0.142
609	Transport, lorry >32t	tkm	0.119	0.136
610	Transport, lorry 16-32t	tkm	0.187	0.214
611	Transport, lorry 20-28t, fleet average	tkm	0.185	0.216
612	Transport, lorry 28t, rape methyl ester 100%	tkm	0.127	0.178
613	Transport, lorry 3.5-16t, fleet average	tkm	0.308	0.356
614	Transport, lorry, 3.5-7.5t load	tkm	0.562	0.664
615	Transport, lorry, 7.5-16t load	tkm	0.269	0.307
616	Transport, tractor and trailer	tkm	0.396	0.469
617	Transport, truck, 16 to 28t with 11t load	tkm	0.318	0.352
618	Transport, truck, 16 to 28t, fleet average	tkm	0.184	0.210
619	Transport, truck, 28t, fleet average	tkm	0.107	0.130
620	Transport, truck, 3,5 to 16t with 12t load	tkm	0.304	0.356
621	Transport, truck, 3,5 to 16t, fleet average	tkm	0.398	0.457

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
622	Transport, truck, 40t load	tkm	0.0951	0.1096
623	Transport, van <3.5t	tkm	2.40	2.93
624	Transport, van 3.5t	tkm	2.45	2.98
625	Transport, VCM freight ship	tkm	0.0067	0.0154
626	Turning, aluminium	kg	16.23	17.61
627	Turning, steel	kg	3.95	4.56
628	Ventilation of dwellings, central, 1 x 720 m3/h, PE ducts, with GHE	m^2a	3.76	4.08
629	Ventilation of dwellings, central, 1 x 720 m3/h, steel ducts, with GHE	m^2a	3.89	4.24
630	Ventilation of dwellings, decentralized, 6 x 120 m3/h, PE ducts, with GHE	m^2a	3.92	4.27
631	Ventilation of dwellings, decentralized, 6 x 120 m3/h, PE ducts, without GHE	m^2a	4.10	4.46
632	Ventilation of dwellings, decentralized, 6 x 120 m3/h, steel ducts, with GHE	m^2a	4.05	4.44
633	Ventilation of dwellings, decentralized, 6 x 120 m3/h, steel ducts, without GHE	m^2a	4.23	4.70
634	Ventilation system, central, 1 x 720 m3/h, PE ducts, with GHE	p	8,840	10,820
635	Ventilation system, central, 1 x 720 m3/h, steel ducts, with GHE	p	13,920	17,110
636	Ventilation system, decentralized, 6 x 120 m3/h, PE ducts, with GHE	p	10,870	12,900
637	Ventilation system, decentralized, 6 x 120 m3/h, PE ducts, without GHE	p	5,860	7,410
638	Ventilation system, decentralized, 6 x 120 m3/h, steel ducts, with GHE	p	15,900	19,200
639	Ventilation system, decentralized, 6 x 120 m3/h, steel ducts, without GHE	p	10,940	16,480
640	Warm impact extrusion, steel	kg	1.87	2.08
641	Welding, arc, aluminium	m	0.339	0.367
642	Welding, arc, steel	m	0.154	0.183
643	Window frame, aluminium, U=1.6 W/m2K	m^2	754	845
644	Window frame, plastic (PVC), U=1.6 W/m2K, at plant	m^2	292	368
645	Window frame, wood-metal, U=1.6 W/m2K, at plant	m^2	395	505
646	Window frame, wood, U=1.5 W/m2K	m^2	215	324
647	Wire drawing, copper	kg	0.718	0.815
648	Wire drawing, steel	kg	0.483	0.524

ICM ID	Product	Unit	Process CFIs (kg of CO_2e per unit)	Hybrid CFIs (kg of CO_2e per unit)
649	Xenon, gaseous	kg	1,440	1,570
650	Zinc , from Imperial smelting furnace	kg	3.43	4.13
651	Zinc coating, coils	m^2	6.58	7.52
652	Zinc coating, pieces, adjustment per um	m^2	0.0881	0.1028
653	Zinc coating, pieces	m^2	9.03	10.31
654	Zinc, from combined metal production, at beneficiation	kg	0.441	0.536
655	Zinc, from combined metal production, at refinery	kg	1.016	1.234
656	Zinc, primary	kg	5.70	6.65

*The Hybrid CFIs in this ICM database are equivalent to the 2015 Hybrid GHG emission intensities (Hybrid GEIs) from the lower double-counting correction scenario ($\mathbf{C}^u$_lower) from Yu and Wiedmann (2018) and Yu et al. (2020).

Chapter 4 References

ABS, 2018. Australian national accounts, input–output tables, 2015-16. Australian Bureau of Statistics, Canberra, Australia: (accessed 25.09.18).

AGEIS, 2017. Australian greenhouse emissions information system (AGEIS). http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/ageis (accessed August 2017).

Crawford, R. H., 2008. Validation of a hybrid life-cycle inventory analysis method. *Journal of Environmental Management, 88*(3), 496-506. doi: 10.1016/j.jenvman.2007.03.024

Crawford, R. H., Bontinck, P.-A., Stephan, A., Wiedmann, T., Yu, M., 2018. Hybrid life cycle inventory methods – a review. *Journal of Cleaner Production, 172*, 1273-1288. doi: 10.1016/j.jclepro.2017.10.176

CRCLCL, 2019. Precinct design assessment: A guide to smart sustainable low carbon urban development. https://apo.org.au/node/247361 (accessed July 2019).

Fouché, M., Crawford, R., Teh, S. H., Rowley, H., Wiedmann, T., 2015. Integrated carbon metrics (ICM): Scoping study results and industry utilisation workshop notes. CRC for Low Carbon Living, Sydney, Australia. http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/icm_scoping_study_report_oct_2015_version151221.pdf (accessed 02.04.16).

Geschke, A., 2017. Balancing datafeed. *Industrial Ecology Virtual Laboratory (Australian IELab).* https://ielab-aus.info (accessed Sept 2017).

Grant, T., 2015. *AusLCI database manual v1.1*. Australian Life Cycle Assessment Society (ALCAS).

Herlihy, J. 2015. *Sustainability of timber as a construction material in Australia.* (Bachelor of Engineering in Environmental Engineering (Hons.)), The University of New South Wales.

Lenzen, M., Geschke, A., Malik, A., Fry, J., Lane, J., Wiedmann, T., Kenway, S., Hoang, K., Cadogan-Cowper, A., 2017. New multi-regional input–output databases for Australia – enabling timely and flexible regional analysis. *Economic Systems Research, 29*(2), 275-295. doi: 10.1080/09535314.2017.1315331

Lenzen, M., Geschke, A., Wiedmann, T., Lane, J., Anderson, N., Baynes, T., Boland, J., Daniels, P., Dey, C., Fry, J., Hadjikakou, M., Kenway, S., Malik, A., Moran, D., Murray, J., Nettleton, S., Poruschi, L., Reynolds, C., Rowley, H., Ugon, J., Webb, D., West, J., 2014. Compiling and using input–output frameworks through collaborative virtual laboratories. *Science of The Total Environment, 485–486*(0), 241-251. doi: 10.1016/j.scitotenv.2014.03.062

Leontief, W., 1970. Environmental repercussions and the economic structure: An input-output approach. *The review of economics and statistics*, 262-271.

McIlvin, K. 2015. *Low-carbon alternatives for steel in australia's construction industry.* (Bachelor of Engineering in Environmental Engineering (Hons.) Honours Thesis), The University of New South Wales.

Miller, R. E., Blair, P. D., 2009. *Input-output analysis: Foundations and extensions*. Cambridge, GBR: Cambridge University Press.

Murray, J., Wood, R., 2010. *The sustainability practitioner's guide to input-output analysis*. Common Ground Publishing LLC, Champaign, USA.

Schinabeck, J., Wiedmann, T., 2014. The long road to zero – embodied carbon in the built environment. https://www.thefifthestate.com.au/columns/spinifex/the-long-road-to-zero-embodied-carbon-in-the-built-environment (accessed 13.11.2014).

Schinabeck, J., Wiedmann, T., Lundie, S., 2016. Assessing embodied carbon in the Australian built environment. http://www.thefifthestate.com.au/columns/spinifex/assessingembodied-carbon-in-the-australian-built-environment/81887 (accessed 26.04.16).

Suh, S., 2004. Functions, commodities and environmental impacts in an ecological–economic model. *Ecological Economics, 48*(4), 451-467.

Teh, S. H., Wiedmann, T., Castel, A., de Burgh, J., 2017. Hybrid life cycle assessment of greenhouse gas emissions from cement, concrete and geopolymer concrete in Australia. *Journal of Cleaner Production, 152*, 312-320. doi: 10.1016/j.jclepro.2017.03.122

Teh, S. H., Wiedmann, T., Crawford, R. H., Xing, K., 2019. Assessing embodied greenhouse gas emissions in the built environment. In P. D. Newton P., Sproul A., White S. (Ed.), *Decarbonising the built environment.* Palgrave Macmillan, Singapore.

Teh, S. H., Wiedmann, T., Schinabeck, J., Rowley, H., Moore, S., 2015. Integrated carbon metrics and assessment for the built environment. *Procedia CIRP, 29*, 480-485. doi: 10.1016/j.procir.2015.02.169

Wiedmann, T., 2010. *Frequently asked questions about input-output analysis*. Centre for Sustainability Accounting (CENSA). Retrieved from www.censa.org.uk

Wiedmann, T., 2017. An input–output virtual laboratory in practice – survey of uptake, usage and applications of the first operational IELab. *Economic Systems Research*, 1-17. doi: 10.1080/09535314.2017.1283295

Wiedmann, T., Crawford, R., Yu, M., Schinabeck, J., Teh, S. H., 2017. The "forgotten" greenhouse gas emissions of our built environment will be a hard nut to crack. https://www.thefifthestate.com.au/columns/spinifex/the-forgotten-greenhouse-gas-emissions-of-our-built-environment-will-be-a-hard-nut-to-crack/92169 (accessed 07.07.17).

Wiedmann, T., Minx, J., 2008. A definition of 'carbon footprint'. *Ecological economics research trends, 1*, 1-11.

Wolfram, P., Wiedmann, T., Diesendorf, M., 2016. Carbon footprint scenarios for renewable electricity in Australia. *Journal of Cleaner Production, 124*, 236-245. doi: 10.1016/j.jclepro.2016.02.080

Yu, M., Robati, M., Oldfield, P., Wiedmann, T., Crawford, R., Nezhad, A. A., Carmichael, D., 2020. The impact of value engineering on embodied greenhouse gas emissions in the built environment: A hybrid life cycle assessment. *Building and Environment, 168*, 106452. doi: 10.1016/j.buildenv.2019.106452

Yu, M., Wiedmann, T., 2018. Implementing hybrid LCA routines in an input–output virtual laboratory. *Journal of Economic Structures, 7*(1), 33. doi: 10.1186/s40008-018-0131-1