



Embodied Carbon - Updating the ICE Database

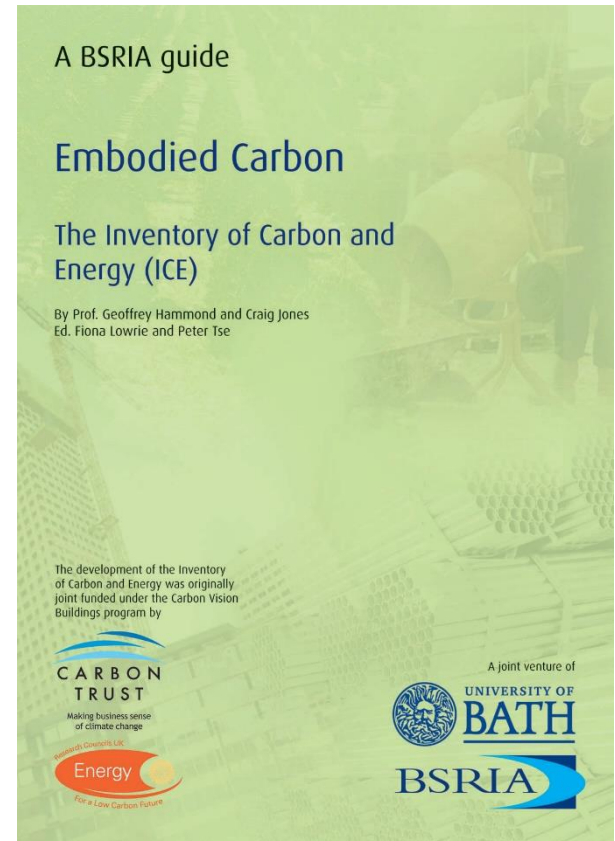
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The Inventory of Carbon & Energy (ICE)

- An **embodied energy and carbon database** for building materials
- Primarily for Construction Materials
- Data for over 200 materials
- Over 30,000 worldwide users
- BSRIA hardcopy published in January 2011
- Excel version free to download from www.circularecology.com/ice-database.html



Updating The Inventory of Carbon & Energy (ICE)

- ICE database is a free resource – will remain free
- Still well used
- However last updated in 2011
 - Data mainly compiled in 2010
- A lot has changed since 2010/11
- Very much due an update
- We obtained funding to update the ICE database
- To keep it freely available

Updating The Inventory of Carbon & Energy (ICE)

- The update to ICE V3 funded by:
 - **Heathrow Airport**
 - **Rail Safety and Standards Board (RSSB)**
 - **Environment Agency**

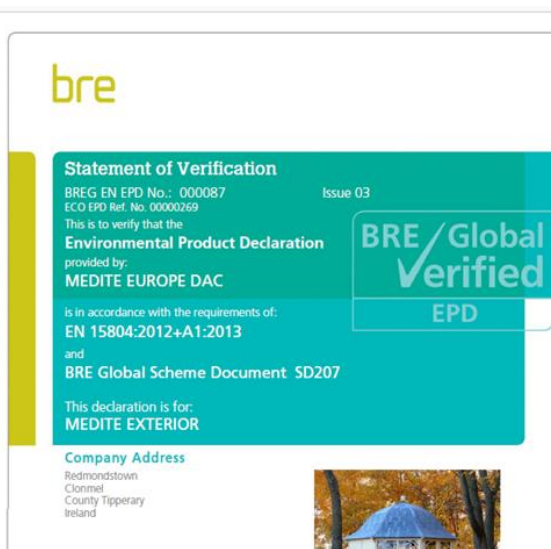
The Wider Landscape – What's Changed Since 2011?



What's Changed Since Last ICE Update

- **EN 15978:2011:** Sustainability of construction works — Assessment of environmental performance of buildings — Calculation method
- **EN 15804:2012:** Sustainability of construction works — **Environmental product declarations** — Core rules for the product category of construction products
- **PAS 2050:2011 Version** - Product carbon footprint standard from BSI. Linked to Carbon Trust Carbon Reduction Label
- **World Resources Institute:** GHG Protocol for Products
- **HM Treasury Infrastructure Carbon Review**, 2013
- **PAS 2080** – Carbon Management in Infrastructure, May 2016
- **ISO 14067** – Carbon footprint of products, 2018

Environmental Product Declarations (EPDs)



LCA Results

(MND = module not declared; MNR = module not relevant; INA = indicator not assessed; AGG = aggregated)

Parameters describing environmental impacts			GWP	ODP	AP	EP	POCP	ADPE	ADPF
			kg CO ₂ equiv.	kg CFC 11 equiv.	kg SO ₂ equiv.	kg (PO ₄) ³⁻ equiv.	kg C ₂ H ₄ equiv.	kg Sb equiv.	MJ, net calorific value.
Product stage	Raw material supply	A1	AGG	AGG	AGG	AGG	AGG	AGG	AGG
	Transport	A2	AGG	AGG	AGG	AGG	AGG	AGG	AGG
	Manufacturing	A3	AGG	AGG	AGG	AGG	AGG	AGG	AGG
	Total (of product stage)	A1-3	-1430	0.0000375	5.05	0.746	1.16	0.000686	12900
Construction process stage	Transport	A4	MND	MND	MND	MND	MND	MND	MND
	Construction	A5	MND	MND	MND	MND	MND	MND	MND

GWP = Global Warming Potential;
 ODP = Ozone Depletion Potential;
 AP = Acidification Potential for Soil and Water;
 EP = Eutrophication Potential;

POCP = Formation potential of tropospheric Ozone;
 ADPE = Abiotic Depletion Potential – Elements;
 ADPF = Abiotic Depletion Potential – Fossil Fuels.



Insights Into ICE Database V3

Scope of Update

- Core scope = Update the key construction materials:
 - Aggregates
 - Aluminium
 - Asphalt
 - Bitumen
 - Bricks
 - Cement
 - Concrete
 - Glass
 - Sand
 - Steel
 - Timber
 - Plastics *{still in progress}*
- This covers the vast majority of embodied carbon for most construction projects

ICE V3.0 Data Collection Stats

- There is a background database, that stores all datapoints collected
- ICE V2.0 – based upon 1,774 datapoints - collected between 2004-2010
- ICE V3.0 - Collected over 1,800 datapoints
 - More data has been logged than all of the previous version of the ICE database together
 - Collected far more data than anticipated
 - Challenge of working with large datasets
 - If 1,800 datapoints each needs editing, 2 min per entry
 - 30 hours at full utilisation

The Inventory of Carbon & Energy (ICE) V2.0

INVENTORY OF CARBON & ENERGY (ICE) SUMMARY				
Materials	Embodied Energy & Carbon Coefficients			Comments
	EE - MJ/kg	EC - kgCO2/kg	EC - kgCO2e/kg	EE = Embodied Energy, EC = Embodied Carbon
<u>Aggregate</u>				
General (Gravel or Crushed Rock)	0.083	0.0048	0.0052	Estimated from measured UK industrial fuel consumption data
<u>Aluminium</u>	Main data source: International Aluminium Institute (IAI) LCA studies (www.world-aluminium.org)			
General	155	8.24	9.16	Assumed (UK) ratio of 25.6% extrusions, 55.7% Rolled & 18.7% castings. Worldwide average recycled content of 33%.
Virgin	218	11.46	12.79	
Recycled	29.0	1.69	1.81	
Cast Products	159	8.28	9.22	Worldwide average recycled content of 33%.
Virgin	226	11.70	13.10	
Recycled	25.0	1.35	1.45	
Extruded	154	8.16	9.08	Worldwide average recycled content of 33%.
Virgin	214	11.20	12.50	
Recycled	34.0	1.98	2.12	
Rolled	155	8.26	9.18	Worldwide average recycled content of 33%.
Virgin	217	11.50	12.80	
Recycled	28	1.67	1.79	
<u>Asphalt</u>				
Asphalt, 4% (bitumen) binder content (by mass)	2.86	0.059	0.066	1.68 MJ/kg Feedstock Energy (Included). Modelled from the bitumen binder content. The fuel consumption of asphalt mixing operations was taken from the Mineral Products Association (MPA). It represents typical UK

The Inventory of Carbon & Energy (ICE) V3

Aggregates and Sand

Version: ICE V 3.0 Beta

Materials	Embodied Carbon - kgCO ₂ e/kg	Comments
general UK, mixture of land won, marine, secondary and recycled, bulk, loose	0.00747	This is an estimate of a market average aggregate. It models a mixture of 64.2% land won, 27.5% recycled and secondary, and 8.3% marine aggregates. Consumption statistics have been taken from a report, by British Marine Aggregates Producer Association, a member of the Mineral Products Association (MPA). [Tenth sustainable development report for the British marine aggregate industry, Dec 2016]. These results are sensitive to the embodied carbon of secondary aggregates, which is a material where data would benefit from improvement. If you know the specific type of aggregates you will use, then it is recommended to use a more specific category of aggregates.
general, virgin mixture of land won and marine, bulk, loose	0.00493	Excludes recycled and secondary aggregate. This has been modelled with 89% land won and 11% marine won aggregate. Consumption statistics have been taken from a report, by British Marine Aggregates Producer Association, a member of the Mineral Products Association (MPA). [Tenth sustainable development report for the British marine aggregate industry, Dec 2016]. The consumption of marine aggregate was taken to be the total marine aggregate production. Of the total, 68% are consumed in the GB market, 11% are sent to the European market and 21% used as beach replenishment or fill.
from virgin land won resources, bulk, loose	0.00438	Based upon the stastical average of all data collected for virgin aggregates in the ICE Database.
from virgin marine resources, bulk, loose	0.00904	Consumption statistics have been taken from a report, by British Marine Aggregates Producer Association, a member of the Mineral Products Association (MPA). [Tenth sustainable development report for the British marine aggregate industry, Dec 2016]. The consumption of marine aggregate was taken to be the total marine aggregate production. The data has been modelled with the average energy consumption for extracting marine aggregates in the UK. The original data did not use all scope emissions factors, instead just scope 1 and 2. The data was therefore used to estimate the full scope 1, 2 and 3 emissions. The impacts to produce aggregates has a particularly large variation in embodied impacts.
from recycled resources, no heat treatment, bulk, loose	0.00610	Based upon the stastical average of all data collected for recycled aggregates with no heat treatment in the ICE Database. Recycled aggregates include aggregates from construction and demolition waste. It does not cover secondary aggregates, such as blast furnace slag, or bottom ash (see separeate category for these). Data for recycled aggregates is more difficult to obtain than for virgin aggregates. There is also a large range in results for recycled aggregates, adding uncertainty into the results.
from recycled resources, with heat treatment, bulk, loose	0.11877	Based upon the stastical average of all data collected for recycled aggregates that have been through heat treatment in the ICE Database. Recycled aggregates include aggregates from construction and demolition waste. It does not cover secondary aggregates such as blast furnace slag, or bottom ash (see separeate category for these). Data for recycled aggregates is more difficult to obtain than for virgin aggregates. There is also a large range in results for recycled aggregates, adding uncertainty into the results.
expanded clay, bulk, loose	0.39321	Based upon the stastical average of all data collected for expanded clay aggregates in the ICE Database.
expanded foamed glass, bulk, loose	0.27763	Based upon the stastical average of all data collected for expanded foamed glass aggregates in the ICE Database.
from secondary resources, bulk, loose	0.06332	Including blast furnace slag, bottom ashes, road planings, mining spoil and other aggregates manufactured from secondary resources. Limited data on the embodied carbon of secondary aggregates was available. There was also limited data on the consumption mixture of secondary aggregates in the UK. The mixture was estimated based upon two sub-regional reports for the Aggregate Minerals survey2015 (AM15). See the references [Table 6.1 in Ref: North East Aggregates Working Party, Annual Aggregates Monitoring report 2015, Dec 2016] and [Table 10B in South East Aggregates Working Party, South East Aggregates Monitoring report 2014 & 2015, Sept 2016]. The data would benefit from covering a wider share of the UK secondary aggregate market.
mixture of recycled and secondary resources, bulk, loose	0.01418	Data on recycled and (particularly) secondary aggregates would benefit from improvement. Limited data on the embodied carbon of secondary aggregates was available. There was also limited data on the consumption mixture of recycled and secondary aggregates in the UK. The mixture was modelled with 33% secondary and 67% recycled aggregates. [Estimated from Ref: Aggregates, cement and ready-mix concrete market investigation, Working paper on market definition for aggregates, cement and RMX. ND67. Available from: https://assets.publishing.service.gov.uk/media/5329dfb440f0b60a730002cf/market_definition_houesestyled.pdf]

Data Quality

- Each datapoint is now scored for data quality

Main Material	Sample Size	DQI Method (Max 5)	DQI Assurance (Max 5)	DQI Temporal (Max 5)	DQI Geographic (Max 5)	DQI Transparency (Max 5)	DQI Sample Size (Max 10)	DQI Total - % (Max 100%)
AggregateSand	164	3.46	2.74	4.62	3.68	2.00	9.00	73%
AggregateSand, Land won gravel and sand	134	3.62	2.72	4.58	3.60	2.00	8.00	70%
AggregateSand, Recycled aggregate, no heat treat	15	2.40	2.67	4.53	3.93	2.00	4.00	56%
AggregateSand, Recycled aggregate, heat treat	6	1.00	3.67	5.00	4.00	2.00	3.00	53%
AggregateSand, Secondary manufactured	4	5.00	3.00	5.00	4.00	2.00	2.00	60%
AggregateSand, Expanded clay agg and sand	2	5.00	2.00	5.00	4.00	2.00	2.00	57%
AggregateSand, Marine sand and aggregate	1	1.00	1.00	5.00	5.00	2.00	1.00	43%
AggregateSand, Expanded foamed glass	1	5.00	2.00	5.00	4.00	2.00	1.00	54%
AggregateSand, General aggregate	1	5.00	3.00	5.00	5.00	2.00	1.00	60%

Main Material	Sample Size	DQI Method (Max 5)	DQI Assurance (Max 5)	DQI Temporal (Max 5)	DQI Geographic (Max 5)	DQI Transparency (Max 5)	DQI Sample Size (Max 10)	DQI Total - % (Max 100%)
Glass	189	5.00	2.97	4.97	3.27	2.00	9.00	78%
Glass, General	109	5.00	2.98	5.00	2.73	2.00	8.00	73%
Glass, Toughened	43	5.00	3.00	5.00	4.00	2.00	5.00	69%
Glass, Glazing, Double	10	5.00	2.90	5.00	4.00	2.00	4.00	65%
Glass, Multi layer safety, unfilled	8	5.00	3.00	5.00	4.00	2.00	3.00	63%
Glass, Multi layer safety, filled core, fire resistant, toughened	6	5.00	3.00	5.00	4.00	2.00	3.00	63%
Glass, Glazing triple	6	5.00	2.83	5.00	4.00	2.00	3.00	62%

Average Method of all Data Collected

- Statistics on the average method of all data collected and logged in the background database
- The data quality indicators score against method
- EN 15804 being top score of 5 out of 5

Method Stated	Fraction of All Data Collected	Totals will not add to 100%. This is because some studies claim adherence to multiple footprint standards.
EN 15804 Data	88.8%	
ISO 14067	4.4%	
ISO 14044 Only	5.2%	
No standardised method claimed	6.7%	

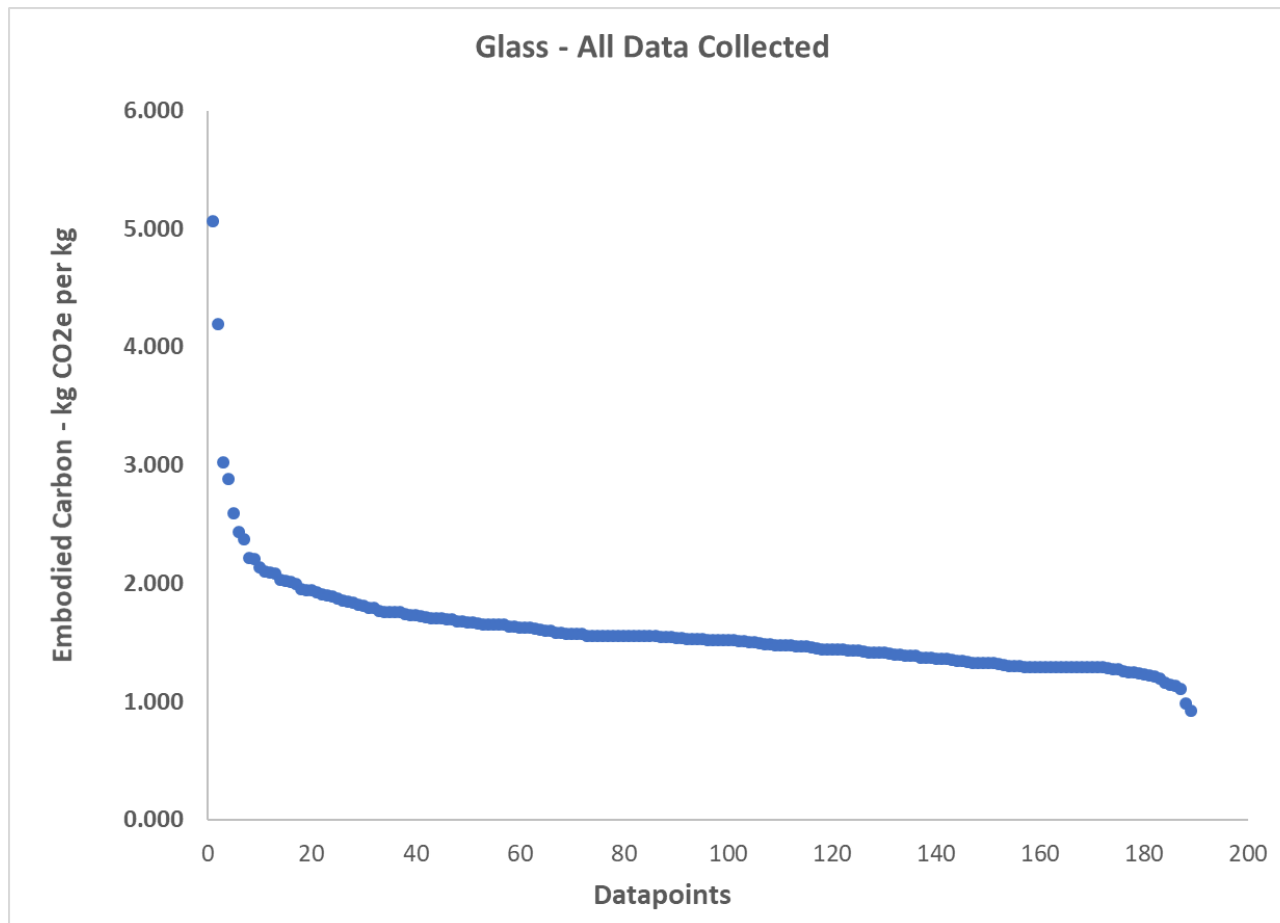
Improved Statistics

Main Material	Sample Size	Average Embodied Carbon (kg CO2e/kg)	Min Embodied Carbon (kg CO2e/kg)	Max Embodied Carbon (kg CO2e/kg)	Standard Deviation Embodied Carbon (kg CO2e/kg)	Variance Based on a Sample (Excel Var Function) Embodied Carbon (kg CO2e/kg)
Glass - All Data Collected	189	1.594	0.920	5.062	0.434	0.188
<i>Glass, General</i>	109	1.437	0.920	2.027	0.191	0.036
<i>Glass, Toughened</i>	43	1.667	1.307	2.440	0.232	0.054
<i>Glass, Glazing, Double</i>	10	1.626	1.331	1.940	0.167	0.028
<i>Glass, Multi layer safety, unfilled</i>	8	1.556	1.422	1.739	0.097	0.009
<i>Glass, Multi layer safety, filled core, fire resistant, toughened</i>	6	2.082	1.947	2.203	0.083	0.007
<i>Glass, Glazing triple</i>	6	1.747	1.653	1.870	0.083	0.007

Main Material	Percentiles - Where Available - kgCO2e per kg						
	10	20	25	50	75	80	90
Glass - All Data Collected	1.291	1.320	1.357	1.530	1.688	1.739	1.947
<i>Glass, General</i>	1.250	1.295	1.296	1.417	1.553	1.555	1.650
<i>Glass, Toughened</i>	1.377	1.486	1.507	1.630	1.765	1.817	1.989
<i>Glass, Glazing, Double</i>	1.345	1.476	1.486	1.640	1.730	1.795	1.928
<i>Glass, Multi layer safety, unfilled</i>		1.443	1.462	1.548	1.634	1.669	
<i>Glass, Multi layer safety, filled core, fire resistant, toughened</i>		1.973	1.996	2.097	2.151	2.175	
<i>Glass, Glazing triple</i>		1.663	1.671	1.718	1.853	1.861	

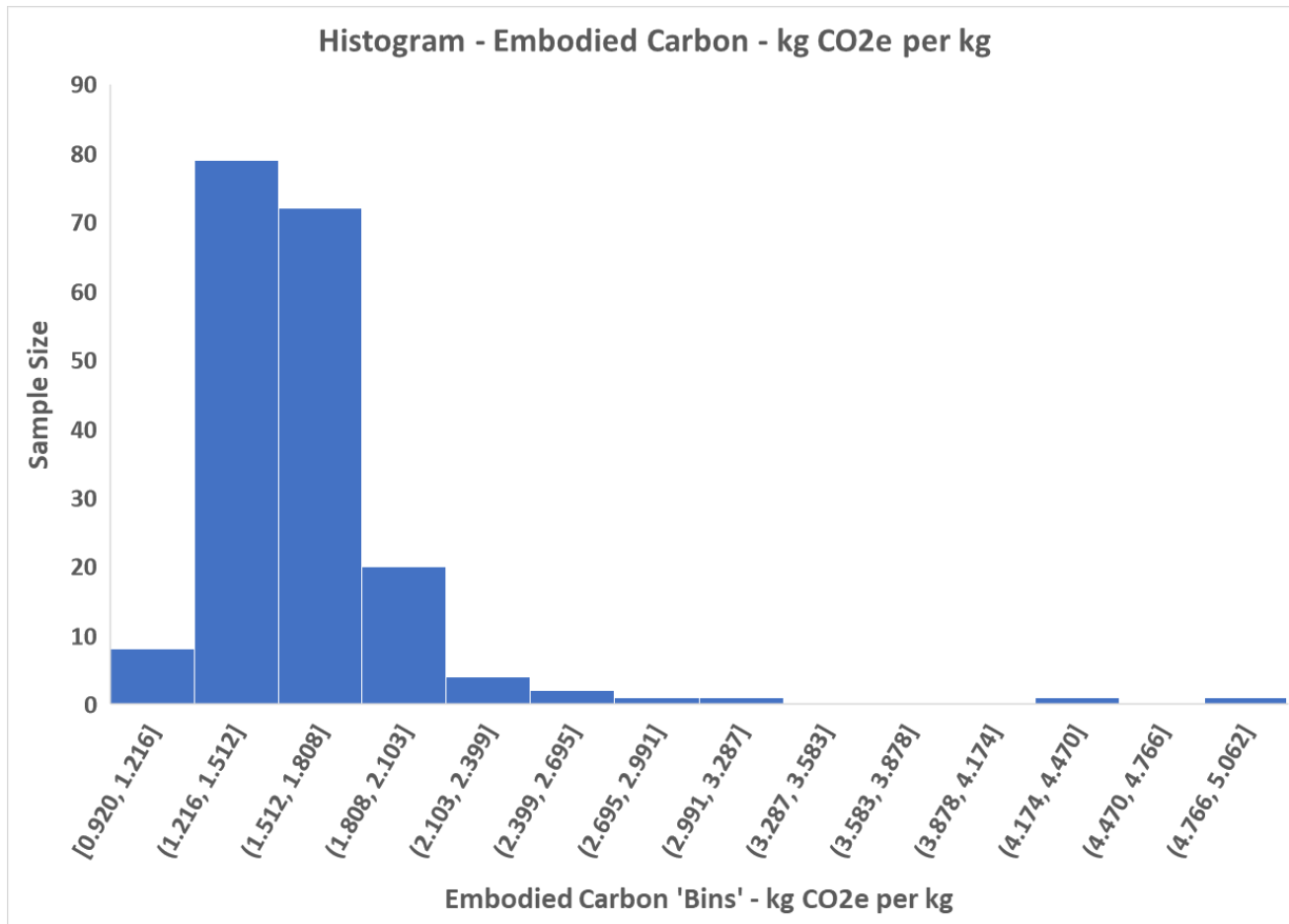
Improved Visualisations

- Distribution charts for all sub-material categories
- The below curve is a typical trend



Improved Visualisations

- Histogram charts for all sub-material categories



Run Your Own Statistical Analysis

- All datapoints provided by material sub-category – to run your own statistical analysis

Datapoint No.	Glass - All Data Collected	Glass, General	Glass, Toughened	Glass, Glazing, Double	Glass, Multi layer safety, unfilled	Glass, Multi layer safety, filled core, fire resistant, toughened	Glass, Glazing triple
1	5.062	2.027	2.440	1.940	1.739	2.203	1.870
2	4.193	2.000	2.213	1.819	1.652	2.134	1.847
3	3.026	1.954	2.080	1.700	1.581	2.100	1.732
4	2.885	1.910	2.030	1.669	1.557	2.095	1.703
5	2.596	1.840	1.928	1.662	1.538	2.012	1.677
6	2.440	1.793	1.900	1.618	1.506	1.947	1.653
7	2.375	1.760	1.890	1.555	1.448		
8	2.213	1.760	1.853	1.490	1.422		
9	2.203	1.730	1.808	1.472			
10	2.134	1.703	1.792	1.331			
11	2.100	1.650	1.765				
12	2.095	1.650	1.760				
13	2.080	1.640	1.760				
14	2.030	1.604	1.720				
15	2.027	1.587	1.712				
16	2.012	1.576	1.710				
17	2.000	1.576	1.695				
18	1.954	1.560	1.680				
19	1.947	1.560	1.673				
20	1.940	1.560	1.656				
21	1.928	1.556	1.640				
22	1.910	1.555	1.630				
23	1.900	1.555	1.627				
24	1.890	1.554	1.627				

Links Directly to EPDs

- Links to hundreds of EPDs on each material profile
- Including EPD number and hyperlink if digitally available on the internet

Item	ICE DB Ref Number	EPD?	Reference Details	Description	Hyperlink
1	363	Yes	EPD Number: BREG EN EPD 000083 published by BRE, 2017	EPD for MEDITE PREMIER	Go To Resource
2	370	Yes	EPD Number: BREG EN EPD 000124 published by BRE, 2017	EPD for Wood for good, 1m3 of kiln dried planed or machined sawn timber used as structural timber.	Go To Resource
3	570	Yes	EPD Number: EPD-EHW-20130013-IBC1-DE published by IBU - Institut Bauen & Umwelt e.V., 2013	EPD for Gypsum fiber board	Go To Resource
4	901	Yes	EPD Number: EPD-EHW-20130012-IBC1-DE published by IBU - Institut Bauen & Umwelt e.V., 2013	EPD for Laminate floor (DPL)	Go To Resource

More Interactive Content

- Some materials are presented in different units

In-Situ Concrete		
SELECT declared unit	kg	This unit is only applied to the in-situ concrete section <<< <<<

- Mini excel tool for steel by recycling assumptions

Enter end of life recover rate, % [Or effective recycled content]	85%	Enter a value from 0-100%. Suggested value of 85%.
----------------------------------------------------------------------	-----	-------------------------------------------------------

- Mini excel tool for precast concrete

SELECT concrete type (scroll up on drop down list)	Results for precast concrete of selected type			
	Declared Units	Embodied Carbon - kgCO ₂ e per unit	Mass per declared unit - kg	Embodied Carbon per kg - kg CO ₂ e per kg
Concrete - Ordinary Portland Cement (OPC) concrete - CEM I based - with total cementitious content of 300 kg per m3 of concrete	m3	353	2380	0.148
Concrete - 50% ggbs cement replacement - with total cementitious content of 320 kg per m3 of concrete	m3	231	2380	0.097
Concrete - 30% pfa cement replacement - with total cementitious content of 320 kg per m3 of concrete	m3	283	2380	0.119

Carbon Calculator for Concrete

- Excel based tool to model embodied carbon of cement, mortar and concrete will be released for the first time

4. RESULTS - Embodied Carbon

Embodied carbon of concrete per m3

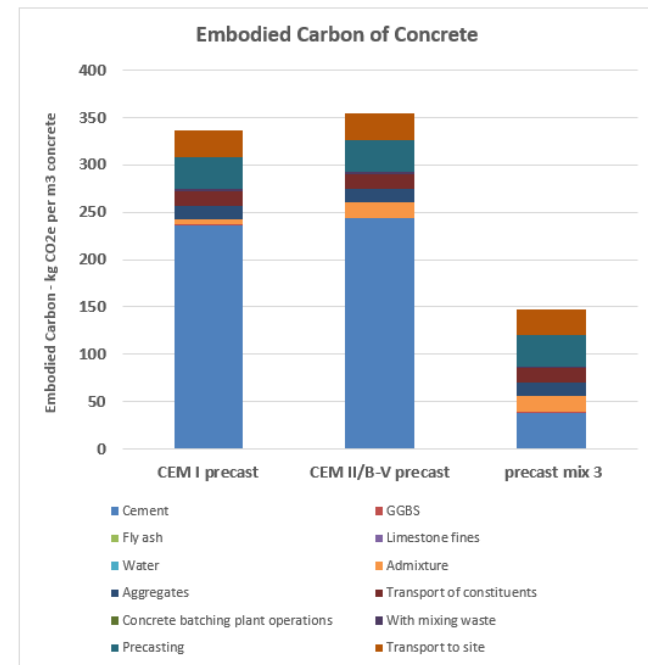
Material	Mix 1	Mix 2	Mix 3
RESULTS - kg CO2e / m3 concrete	336	354	148

Embodied carbon of concrete per kg concrete

RESULTS - kg CO2e / kg concrete	0.143	0.149	0.062
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Results - Contribution Chart %

	Mix 1	Mix 2	Mix 3
Material	CEM I precast	CEM II/B-V precast	precast mix 3
Cement	70.1%	68.9%	25.7%
GBFS	0.3%	0.0%	1.3%
Fly ash	0.0%	0.0%	0.0%
Limestone fines	0.0%	0.0%	0.0%
Water	0.0%	0.0%	0.0%
Admixture	1.5%	4.7%	11.3%
Aggregates	4.4%	4.0%	9.6%
Transport of constituents	4.4%	4.2%	10.1%
Concrete batching plant operations	0.0%	0.0%	0.0%
With mixing waste	0.8%	0.8%	0.6%
Precasting	9.9%	9.5%	22.7%
Transport to site	8.4%	7.8%	18.7%



Data for Building Elements

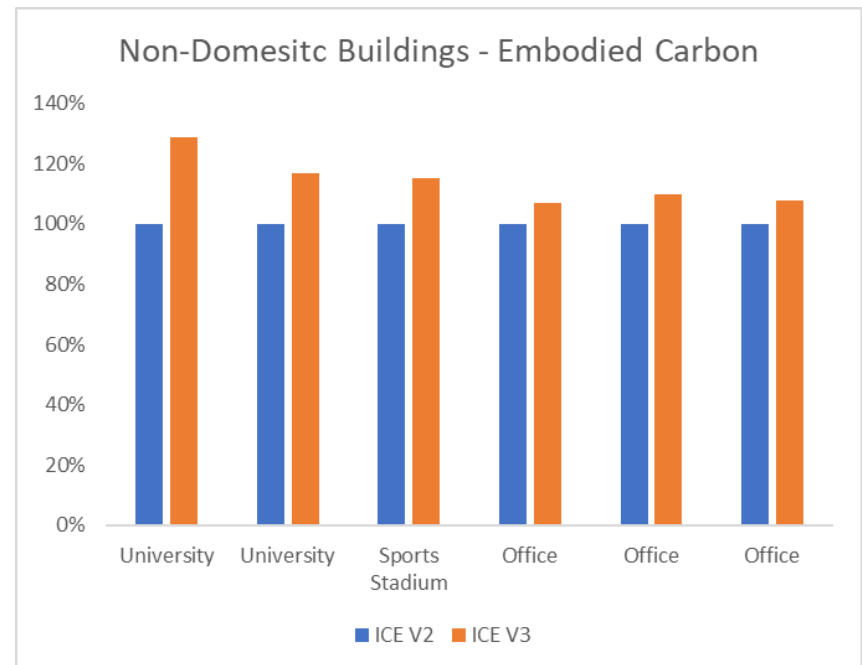
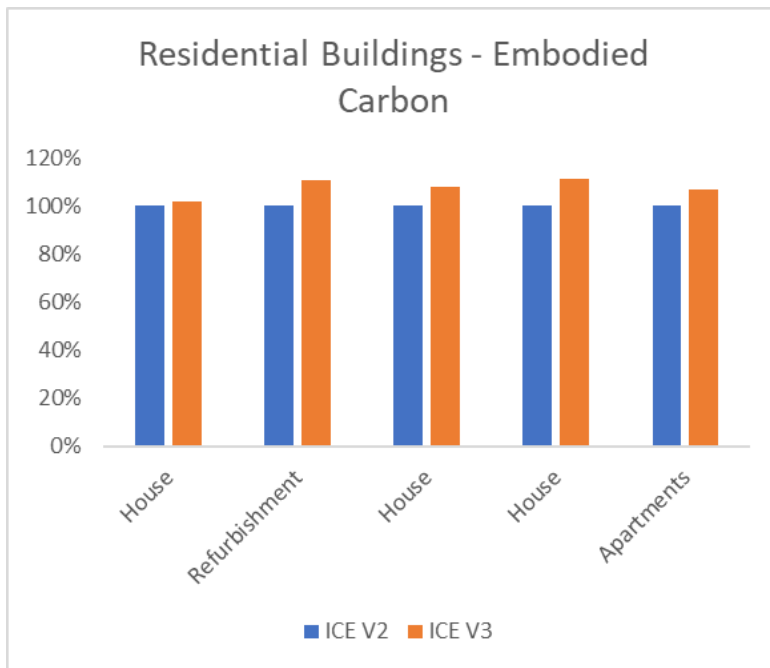
- Data has been added for:
 - Brick walls, per m²
 - Single and double skin walls
 - Concrete block walls, per m²
 - By various block types and dimensions
 - Glass by thickness of glazing, per m²
 - And single, double or triple glazed
 - Asphalt road surface layers, by 100mm layer thickness per m²

Analysis

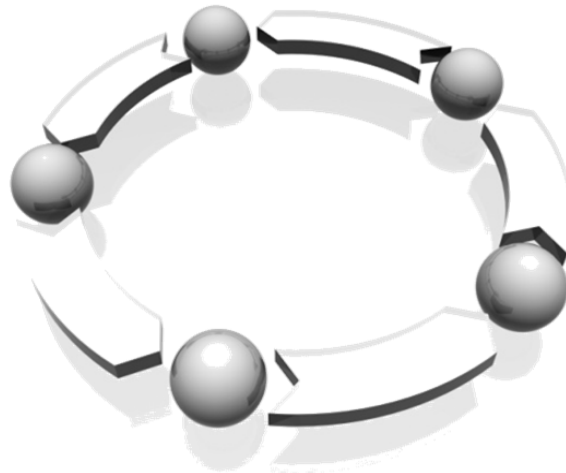


ICE V3 – Difference to Embodied Carbon Results

- We have tested ICE V3, in comparison to ICE V2.0 on several buildings
- This should be considered as a high level (first order) analysis
- Results suggest that embodied carbon may be higher than previously thought...



How To Access ICE V3



- It is freely available on the website
 - www.circularecology.com/embodied-energy-and-carbon-footprint-database.html
- That page will always have the latest version publicly available

Acknowledgements

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- Rail Safety and Standards Board (RSSB)
- Environment Agency