INVENTORY OF CARBON & ENERGY (ICE) Version 2.0

Summary Tables

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Full versions of ICE available from: www.bath.ac.uk/mech-eng/sert/embodied/

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
Aggregate				
General (Gravel or Crushed Rock)	**0.083**	**0.0048**	**0.0052**	Estimated from measured UK industrial fuel consumption data
Aluminium	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	
Asphalt				
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 industrial data. Feedstock energy is from the bitumen content.
Asphalt, 5% binder content	**3.39**	**0.064**	**0.071**	2.10 MJ/kg Feedstock Energy (Included). Comments from 4% mix also apply.
Asphalt, 6% binder content	**3.93**	**0.068**	**0.076**	2.52 MJ/kg Feedstock Energy (Included). Comments from 4% mix also apply.
Asphalt, 7% binder content	**4.46**	**0.072**	**0.081**	2.94 MJ/kg Feedstock Energy (Included). Comments from 4% mix also apply.
Asphalt, 8% binder content	**5.00**	**0.076**	**0.086**	3.36 MJ/kg Feedstock Energy (Included). Comments from 4% mix also apply.
Bitumen				
General	**51**	**0.38 - 0.43 (?)**	**0.43 - 0.55 (?)**	42 MJ/kg Feedstock Energy (Included). Feedstock assumed to be typical energy content of Bitumen. Carbon dioxide emissions are particularly difficult to estimate, range given.
Brass				
General	**44.00**	**2.46 (?)**	**2.64 (?)**	Poor data availability. It is believed that the data may be largely dependent upon ore grade. Poor carbon data, making estimate of embodied carbon difficult.
Virgin	80.00	4.47 (?)	4.80 (?)	
Recycled	20.00	1.12 (?)	1.20 (?)	
Bricks				
General (Common Brick)	**3.00**	**0.23**	**0.24**	
EXAMPLE: Single Brick	**6.9 MJ per brick**	**0.53 kgCO2 per brick**	**0.55**	Assuming 2.3 kg per brick.
Limestone	**0.85**	**?**	**-**	
Bronze				
General	**69.0 (?)**	**3.73 (?)**	**4.0 (?)**	Average of the only two references
Carpet				
General Carpet	**74 (187 per sqm)**	**3.9 (9.8 per sqm)**	**-**	For per square meter estimates see material profile. Difficult to estimate, taken from Ref. 94.
Felt (Hair and Jute) Underlay	**19.00**	**0.97**	**-**	Ref. 94.
Nylon (Polyamide), pile weight 300 g/m2	**130 MJ per sqm**	**6.7 (GWP) per sqm**	**6.7 (GWP) per sqm**	Total weight of this carpet 1,477 g/m2. See Refs. 277 & 279. These carpets (inc. below) are a tufted surface pile made of 100% nylon (polyamide) with a woven textile backing and flame proofed on the basis of aluminium hydroxide.
Nylon (Polyamide), pile weight 500 g/m2	**180 MJ per sqm**	**9.7 (GWP) per sqm**	**9.7 (GWP) per sqm**	Total weight of this carpet 1,837 g/m2. See Refs. 277 & 279.
Nylon (Polyamide), pile weight 700 g/m2	**230 MJ per sqm**	**12.7 (GWP) per sqm**	**12.7 (GWP) per sqm**	Total weight of this carpet 2,147 g/m2. See Refs. 277 & 279.
Nylon (Polyamide), pile weight 900 g/m2	**277 MJ per sqm**	**15.6 (GWP) per sqm**	**15.6 (GWP) per sqm**	Total weight of this carpet 2,427 g/m2. See Refs. 277 & 279.
Nylon (Polyamide), pile weight 1100 g/m2	**327 MJ per sqm**	**18.4 (GWP) per sqm**	**18.4 (GWP) per sqm**	Total weight of this carpet 2,677 g/m2. See Refs. 277 & 279.
Carpet tiles, nylon (Polyamide), pile weight 300 g/m2	**178 MJ per sqm**	**7.75 (GWP) per sqm**	**7.75 (GWP) per sqm**	Total weight of this carpet 4,123 g/m2. See Refs. 277 & 279. These carpet tiles (inc. below) are a tufted surface pile made of 100% nylon (polyamide) fleece-covered bitumen backing and flame-proofed on the basis of aluminium hydroxide
Carpet tiles, nylon (Polyamide), pile weight 500 g/m2	**229 MJ per sqm**	**10.7 (GWP) per sqm**	**10.7 (GWP) per sqm**	Total weight of this carpet 4,373 g/m2. See Refs. 277 & 279.
Carpet tiles, nylon (Polyamide), pile weight 700 g/m2	**279 MJ per sqm**	**13.7 (GWP) per sqm**	**13.7 (GWP) per sqm**	Total weight of this carpet 4,623 g/m2. See Refs. 277 & 279.
Carpet tiles, nylon (Polyamide), pile weight 900 g/m2	**328 MJ per sqm**	**16.7 (GWP) per sqm**	**16.7 (GWP) per sqm**	Total weight of this carpet 4,873 g/m2. See Refs. 277 & 279.
Carpet tiles, nylon (Polyamide), pile weight 1100 g/m2	**378 MJ per sqm**	**19.7 (GWP) per sqm**	**19.7 (GWP) per sqm**	Total weight of this carpet 5,123 g/m2. See Refs. 277 & 279.
Polyethylterepthalate (PET)	**106.50**	**5.56**	**-**	Includes feedstock energy
Polypropylene	**95.40**	**4.98**	**-**	Includes feedstock energy, for per square meter see material profile
Polyurethane	**72.10**	**3.76**	**-**	Includes feedstock energy
Rubber	**67.5 to 140**	**3.61 to 7.48**	**-**	

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Saturated Felt Underlay (impregnated with Asphalt or tar)	31.70	1.65	-	Ref. 94.
Wool	106.00	5.53	-	For per square meter see material profile. See Refs. 63, 201, 202 & 281 (Same author).
Cement				
General (UK weighted average)	4.5	0.73	0.74	Weighted average of all cement consumed within the UK. This includes all factory made cements (CEM I, CEM II, CEM III, CEM IV) and further blending of fly ash and ground granulated blast furnace slag. This data has been estimated from the British Cement Association's factsheets (see Ref. 59). 23% cementitious additions on average.
Average CEM I Portland Cement, 94% Clinker	5.50	0.93	0.95	This is a standard cement with no cementitious additions (i.e. fly ash or blast furnace slag). Composition 94% clinker, 5% gypsum, 1% minor additional constituents (mac's). This data has been estimated from the British Cement Association's factsheets (see Ref. 59.).
6-20% Fly Ash (CEM II/A-V)	5.28 to 4.51	0.88 (@ 6%) to 0.75 (@ 20%)	0.89 to 0.76	See material profile for further details.
21-35% Fly Ash (CEM II/B-V)	4.45 to 3.68	0.74 to 0.61	0.75 to 0.62	
21-35% GGBS (CEM II/B-S)	4.77 to 4.21	0.76 to 0.64	0.77 to 0.65	
36-65% GGBS (CEM III/A)	4.17 to 3.0	0.63 to 0.38	0.64 to 0.39	
66-80% GGBS (CEM II/B)	2.96 to 2.4	0.37 to 0.25	0.38 to 0.26	
Fibre Cement Panels - Uncoated	10.40	1.09	-	Few data points. Selected data modified from Ref. 107.
Fibre Cement Panels - (Colour) Coated	15.30	1.28	-	
Mortar (1:3 cement:sand mix)	1.33	0.208	0.221	Values estimated from the ICE Cement, Mortar & Concrete Model
Mortar (1:4)	1.11	0.171	0.182	
Mortar (1:5)	0.97	0.146	0.156	
Mortar (1:6)	0.85	0.127	0.136	
Mortar (1:½:4½ Cement:Lime:Sand mix)	1.34	0.200	0.213	
Mortar (1:1:6 Cement:Lime:Sand mix)	1.11	0.163	0.174	
Mortar (1:2:9 Cement:Lime:Sand mix)	1.03	0.145	0.155	
Cement stabilised soil @ 5%	0.68	0.060	0.061	Assumed 5% cement content.
Cement stabilised soil @ 8%	0.83	0.082	0.084	Assumed 8% stabiliser contents (6% cement and 2% quicklime)
Ceramics				
General	10.00	0.66	0.70	Very large data range, difficult to select values for general ceramics.
Fittings	20.00	1.07	1.14	Ref. 1.
Sanitary Products	29.00	1.51	1.61	Limited data.
Tiles and Cladding Panels	12.00	0.74	0.78	Difficult to select, large range, limited data. See Ref. 292.
Clay				
General (Simple Baked Products)	3.00	0.23	0.24	General simple baked clay products (inc. terracotta and bricks)
Tile	6.50	0.45	0.48	
Vitrified clay pipe DN 100 & DN 150	6.20	0.44	0.46	
Vitrified clay pipe DN 200 & DN 300	7.00	0.48	0.50	
Vitrified clay pipe DN 500	7.90	0.52	0.55	
Concrete				
General	0.75	0.100	0.107	**It is strongly recommended to avoid selecting a 'general' value for concrete.** Selecting data for a specific concrete type (often a ready mix concrete) will give greater accuracy, please see material profile. Assumed cement content 12% by mass.
16/20 Mpa	0.70	0.093	0.100	Using UK weighted average cement (more representative of 'typical' concrete mixtures).
20/25 MPa	0.74	0.100	0.107	
25/30 MPa	0.78	0.106	0.113	
28/35 MPa	0.82	0.112	0.120	
32/40 MPa	0.88	0.123	0.132	
40/50 MPa	1.00	0.141	0.151	

% Cement Replacement - Fly Ash	0%	15%	30%	0%	15%	30%	0%	15%	30%	Note 0% is a concrete using a CEM I cement (not typical)
GEN 0 (6/8 MPa)	0.55	0.52	0.47	0.071	0.065	0.057	0.076	0.069	0.061	**Compressive strength designation C6/8 Mpa. 28 day compressive strength under British cube method of 8 MPa, under European cylinder method 6 MPa.** Possible uses: Kerb bedding and backing. Data is only cradle to factory gate but beyond this the average delivery distance of ready mix concrete is 8.3 km by road (see Ref. 244).
GEN 1 (8/10 MPa)	0.70	0.65	0.59	0.097	0.088	0.077	0.104	0.094	0.082	Possible uses: mass concrete, mass fill, mass foundations, trench foundations, blinding, strip footing.
GEN 2 (12/15 MPa)	0.76	0.71	0.64	0.106	0.098	0.087	0.114	0.105	0.093	-
GEN 3 (16/20 MPa)	0.81	0.75	0.68	0.115	0.105	0.093	0.123	0.112	0.100	Possible uses: garage floors.
RC 20/25 (20/25 MPa)	0.86	0.81	0.73	0.124	0.114	0.101	0.132	0.122	0.108	-
RC 25/30 (25/30 MPa)	0.91	0.85	0.77	0.131	0.121	0.107	0.140	0.130	0.115	Possible uses: reinforced foundations.
RC 28/35 (28/35 MPa)	0.95	0.90	0.82	0.139	0.129	0.116	0.148	0.138	0.124	Possible uses: reinforced foundations, ground floors.
RC 32/40 (32/40 MPa)	1.03	0.97	0.89	0.153	0.143	0.128	0.163	0.152	0.136	Possible uses: structural purposes, in situ floors, walls, superstructure.
RC 40/50 (40/50 MPa)	1.17	1.10	0.99	0.176	0.164	0.146	0.188	0.174	0.155	Possible uses: high strength applications, precasting.
PAV1	0.95	0.89	0.81	0.139	0.129	0.115	0.148	0.138	0.123	Possible uses: domestic parking and outdoor paving.
PAV2	1.03	0.97	0.89	0.153	0.143	0.128	0.163	0.152	0.137	Possible uses: heavy duty outdoor paving.

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% Cement Replacement - Blast Furnace Slag	0%	25%	50%	0%	25%	50%	0%	15%	30%	Note 0% is a concrete using a CEM I cement
GEN 0 (6/8 MPa)	**0.55**	0.48	0.41	**0.071**	0.056	0.042	**0.076**	0.060	0.045	
GEN 1 (8/10 MPa)	**0.70**	0.60	0.50	**0.097**	0.075	0.054	**0.104**	0.080	0.058	
GEN 2 (12/15 MPa)	**0.76**	0.62	0.55	**0.106**	0.082	0.061	**0.114**	0.088	0.065	
GEN 3 (16/20 MPa)	**0.81**	0.69	0.57	**0.115**	0.090	0.065	**0.123**	0.096	0.070	
RC 20/25 (20/25 MPa)	**0.86**	0.74	0.62	**0.124**	0.097	0.072	**0.132**	0.104	0.077	
RC 25/30 (25/30 MPa)	**0.91**	0.78	0.65	**0.131**	0.104	0.076	**0.140**	0.111	0.081	See fly ash mixtures
RC 28/35 (28/35 MPa)	**0.95**	0.83	0.69	**0.139**	0.111	0.082	**0.148**	0.119	0.088	
RC 32/40 (32/40 MPa)	**1.03**	0.91	0.78	**0.153**	0.125	0.094	**0.163**	0.133	0.100	
RC 40/50 (40/50 MPa)	**1.17**	1.03	0.87	**0.176**	0.144	0.108	**0.188**	0.153	0.115	
PAV1	**0.95**	0.82	0.70	**0.139**	0.111	0.083	**0.148**	0.118	0.088	
PAV2	**1.03**	0.91	0.77	**0.153**	0.125	0.094	**0.163**	0.133	0.100	

COMMENTS

The first column represents standard concrete, created with a CEM I Portland cement. The other columns are estimates based on a direct substitution of fly ash or blast furnace slag in place of the cement content. The ICE Cement, Mortar & Concrete Model was applied. **Please see important notes in the concrete material profile.**

REINFORCED CONCRETE - Modification Factors				
For reinforcement add this value to the appropriate concrete coefficient for each 100 kg of rebar per m3 of concrete	**1.04**	**0.072**	**0.077**	Add for each 100 kg steel rebar per m3 concrete. Use multiple of this value, i.e. for 150 kg steel use a factor of 1.5 times these values.
EXAMPLE: Reinforced RC 25/30 MPa (with 110 kg per m3 concrete)	**1.92 MJ/kg (0.78 + 1.04 * 1.1)**	**0.185 kgCO2/kg (0.106 + 0.072 * 1.1)**	**0.198 kgCO2/kg (0.113 + 0.077 * 1.1)**	with 110 kg rebar per m3 concrete. UK weighted average cement. This assumes the UK typical steel scenario (59% recycled content). Please consider if this is in line with the rest of your study (goal and scope) or the requirements of a predefined method.
PRECAST (PREFABRICATED) CONCRETE - Modification Factors				
For precast add this value to the selected coefficient of the appropriate concrete mix	**0.45**	**0.027**	**0.029**	For each 1 kg precast concrete. This example is using a RC 40/50 strength class and is not necessarily indicative of an average precast product. Includes UK recorded plant operations and estimated transportation of the constituents to the factory gate (38km aggregates, estimated 100km cement). Data is only cradle to factory gate but beyond this the average delivery distance of precast is 155km by road (see Ref. 244). UK weighted average cement. See also the new report on precast concrete pipes (Ref 300).
EXAMPLE: Precast RC 40/50 MPa	**1.50 MJ/kg (1.00 + 0.50)**	**0.168 kgCO2/kg (0.141 + 0.027)**	**0.180 kgCO2/kg (0.151 + 0.029)**	
EXAMPLE: Precast RC 40/50 with reinforcement (with 80kg per m^3)	**2.33 MJ/kg (1.50 + 1.04 * 0.8)**	**0.229 kgCO2/kg (0.171 + 0.072 * 0.8)**	**0.242 kgCO2/kg (0.180 + 0.077 * 0.8)**	
CONCRETE BLOCKS (ICE CMC Model Values)				
Block - 8 MPa Compressive Strength	**0.59**	**0.059**	**0.063**	Estimated from the concrete block mix proportions, plus an allowance for concrete block curing, plant operations and transport of materials to factory gate.
Block - 10 MPa	**0.67**	**0.073**	**0.078**	
Block -12 MPa	**0.72**	**0.082**	**0.088**	
Block -13 MPa	**0.83**	**0.100**	**0.107**	
Autoclaved Aerated Blocks (AAC's)	**3.50**	**0.24 to 0.375**	**-**	Not ICE CMC model results.
NOMINAL PROPORTIONS METHOD (Volume), Proportions from BS 8500:2006 (ICE Cement, Mortar & Concrete Model Calculations)				
1:1:2 Cement:Sand:Aggregate	**1.28**	**0.194**	**0.206**	High strength concrete. All of these values were estimated assuming the **UK average content of cementitious additions** (i.e. fly ash, GGBS) for **factory supplied cements** in the UK, see Ref. 59, plus the proportions of other constituents.
1:1.5:3	**0.99**	**0.145**	**0.155**	Often used in floor slab, columns & load bearing structure.
1:2:4	**0.82**	**0.116**	**0.124**	Often used in construction of buildings under 3 storeys.
1:2.5:5	**0.71**	**0.097**	**0.104**	
1:3:6	**0.63**	**0.084**	**0.090**	Non-structural mass concrete.
1:4:8	**0.54**	**0.069**	**0.074**	
BY CEM I CEMENT CONTENT - kg CEM I cement content per cubic meter concrete (ICE CMC Model Results)				
120 kg / m^3 concrete	**0.49**	**0.060**	**0.064**	Assumed density of 2,350 kg/m3. Interpolation of the CEM I cement content is possible. These numbers assume the **CEM I cement content (not the total cementitious content**, i.e. they do not include cementitious additions). They may also be used for fly ash mixtures without modification, but they are likely to slightly underestimate mixtures that have additional GGBS due to the higher embodied energy and carbon of GGBS (in comparison to aggregates and fly ash).
200 kg / m^3 concrete	**0.67**	**0.091**	**0.097**	
300 kg / m^3 concrete	**0.91**	**0.131**	**0.140**	
400kg / m^3 concrete	**1.14**	**0.170**	**0.181**	
500 kg / m^3 concrete	**1.37**	**0.211**	**0.224**	
MISCELLANEOUS VALUES				
Fibre-Reinforced	**7.75 (?)**	**0.45 (?)**	**-**	Literature estimate, likely to vary widely. High uncertainty.
Very High GGBS Mix	**0.66**	**0.049**	**0.050**	Data based on Lafarge 'Envirocrete', which is a C28/35 MPa, very high GGBS replacement value concrete
Copper				
EU Tube & Sheet	**42.00**	**2.60**	**2.71**	EU production data, estimated from Kupfer Institut LCI data. 37% recycled content (the 3 year world average). World average data is expected to be higher than these values.
Virgin	57.00	3.65	3.81	
Recycled	16.50	0.80	0.84	
Recycled from high grade scrap	**18 (?)**	**1.1 (?)**		Uncertain, difficult to estimate with the data available.
Recycled from low grade scrap	**50 (?)**	**3.1 (?)**		

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Glass				
Primary Glass	15.00	0.86	0.91	Includes process CO2 emissions from primary glass manufacture.
Secondary Glass	11.50	0.55	0.59	EE estimated from Ref 115.
Fibreglass (Glasswool)	28.00	1.54	-	Large data range, but the selected value is inside a small band of frequently quoted values.
Toughened	23.50	1.27	1.35	Only three data sources
Insulation				
General Insulation	45.00	1.86	-	Estimated from typical market shares. Feedstock Energy 16.5 MJ/kg (Included)
Cellular Glass	27.00	-	-	Ref. 54.
Cellulose	0.94 to 3.3	-	-	
Cork	4.00	0.19	-	Ref. 55.
Fibreglass (Glasswool)	28.00	1.35	-	Poor data difficult to select appropriate value
Flax (Insulation)	39.50	1.70	-	Ref. 2. 5.97 MJ/kg Feedstock Energy (Included)
Mineral wool	16.60	1.20	1.28	
Paper wool	20.17	0.63	-	Ref. 2
Polystyrene	See Plastics	See Plastics	-	see plastics
Polyurethane	See Plastics	See Plastics	-	see plastics
Rockwool	16.80	1.05	1.12	Cradle to Grave
Woodwool (loose)	10.80	-	-	Ref. 205.
Woodwool (Board)	20.00	0.98	-	Ref. 55.
Wool (Recycled)	20.90	-	-	Refs. 63, 201, 202 & 281.
Iron				
General	25.00	1.91 (?)	2.03	It was difficult to estimate the embodied energy and carbon of iron with the data available.
Lead				
General	25.21	1.57	1.67	Allocated (divided) on a mass basis, assumes recycling rate of 61%
Virgin	49.00	3.18	3.37	
Recycled	10.00	0.54	0.58	Scrap batteries are a main feedstock for recycled lead
Lime				
General	5.30	0.76	0.78	Embodied carbon was difficult to estimate
Linoleum				
General	25.00	1.21	-	Data difficult to select, large data range.
Miscellaneous				
Asbestos	7.40	-	-	Ref. 4.
Calcium Silicate Sheet	2.00	0.13	-	Ref. 55.
Chromium	83	5.39	-	Ref. 22.
Cotton, Padding	27.10	1.28	-	Ref. 38.
Cotton, Fabric	143	6.78	-	Ref. 38.
Damp Proof Course/Membrane	134 (?)	4.2 (?)	-	Uncertain estimate.
Felt General	36	-	-	
Flax	33.50	1.70	-	Ref. 2.
Fly Ash	0.10	0.008	-	No allocation from fly ash producing system.
Grit	0.12	0.01	-	Ref. 114.
Ground Limestone	0.62	0.032	-	
Carpet Grout	30.80	-	-	Ref. 169.
Glass Reinforced Plastic - GRP - Fibreglass	100	8.10	-	Ref. 1.
Lithium	853	5.30	-	Ref. 22.
Mandolite	63	1.40	-	Ref. 1.
Mineral Fibre Tile (Roofing)	37	2.70	-	Ref. 1.
Manganese	52	3.50	-	Ref. 22.
Mercury	87	4.94	-	Ref. 22.
Molybedenum	378	30.30	-	Ref. 22.
Nickel	164	12.40	-	Ref. 114.
Perlite - Expanded	10.00	0.52	-	Ref. 114.
Perlite - Natural	0.66	0.03	-	Ref. 114.
Quartz powder	0.85	0.02	-	Ref. 114.
Shingle	11.30	0.30	-	Ref. 70.
Silicon	2355	-	-	Ref. 167.
Slag (GGBS)	1.60	0.083	-	Ground Granulated Blast Furnace Slag (GGBS), economic allocation.
Silver	128.20	6.31	-	Ref. 148.
Straw	0.24	0.01	-	Refs. 63, 201, 202 & 281.
Terrazzo Tiles	1.40	0.12	-	Ref. 1.
Vanadium	3710	228	-	Ref. 22.
Vermiculite - Expanded	7.20	0.52	-	Ref. 114.
Vermiculite - Natural	0.72	0.03	-	Ref. 114.
Vicuclad	70.00	-	-	Ref. 1.
Water	0.01	0.001	-	
Wax	52.00	-	-	Ref. 169.
Wood stain/Varnish	50.00	5.35	-	Ref. 1.
Yttrium	1470	84.00	-	Ref. 22.
Zirconium	1610	97.20	-	Ref. 22.
Paint				
General	70.00	2.42	2.91	Large variations in data, especially for embodied carbon. Includes feedstock energy. Water based paints have a 70% market share. Water based paint has a lower embodied energy than solvent based paint.
EXAMPLE: Single Coat	10.5 MJ/Sqm	0.36 kgCO2/Sqm	0.44	Assuming 6.66 Sqm Coverage per kg
EXAMPLE: Double Coat	21.0 MJ/Sqm	0.73 kgCO2/Sqm	0.87	Assuming 3.33 Sqm Coverage per kg
EXAMPLE: Triple Coat	31.5 MJ/Sqm	1.09 kgCO2/Sqm	1.31	Assuming 2.22 Sqm Coverage per kg
Waterborne Paint	59.00	2.12	2.54	Waterborne paint has a 70% of market share. Includes feedstock energy.
Solventborne Paint	97.00	3.13	3.76	Solventborne paint has a 30% share of the market. Includes feedstock energy. It was difficult to estimate carbon emissions for Solventborne paint.

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
Paper				
Paperboard (General for construction use)	24.80	1.29	-	Excluding calorific value (CV) of wood, excludes carbon sequestration/biogenic carbon storage.
Fine Paper	28.20	1.49	-	Excluding CV of wood, excludes carbon sequestration
EXAMPLE: 1 packet A4 paper	70.50	3.73	-	Standard 80g/sqm printing paper, 500 sheets a pack. Doesn't include printing.
Wallpaper	36.40	1.93	-	
Plaster				
General (Gypsum)	1.80	0.12	0.13	Problems selecting good value, inconsistent figures, West et al believe this is because of past aggregation of EE with cement
Plasterboard	6.75	0.38	0.39	See Ref [WRAP] for further info on GWP data, including disposal impacts which are significant for Plasterboard.
Plastics	Main data source: Plastics Europe (www.plasticseurope.org) ecoprofiles			
General	80.50	2.73	3.31	35.6 MJ/kg Feedstock Energy (Included). Determined by the average use of each type of plastic used in the European construction industry.
ABS	95.30	3.05	3.76	48.6 MJ/kg Feedstock Energy (Included)
General Polyethylene	83.10	2.04	2.54	54.4 MJ/kg Feedstock Energy (Included). Based on average consumption of types of polyethylene in European construction
High Density Polyethylene (HDPE) Resin	76.70	1.57	1.93	54.3 MJ/kg Feedstock Energy (Included). Doesn't include the final fabrication.
HDPE Pipe	84.40	2.02	2.52	55.1 MJ/kg Feedstock Energy (Included)
Low Density Polyethylene (LDPE) Resin	78.10	1.69	2.08	51.6 MJ/kg Feedstock Energy (Included). Doesn't include the final fabrication
LDPE Film	89.30	2.13	2.60	55.2 MJ/kg Feedstock Energy (Included)
Nylon (Polyamide) 6 Polymer	120.50	5.47	9.14	38.6 MJ/kg Feedstock Energy (Included). Doesn't include final fabrication. Plastics Europe state that two thirds of nylon is used as fibres (textiles, carpets…etc) in Europe and that most of the remainder as injection mouldings. Dinitrogen monoxide and methane emissions are very significant contributors to GWP.
Nylon (polyamide) 6,6 Polymer	138.60	6.54	7.92	50.7 MJ/kg Feedstock Energy (Included). Doesn't include final fabrication (i.e. injection moulding). See comments for Nylon 6 polymer.
Polycarbonate	112.90	6.03	7.62	36.7 MJ/kg Feedstock Energy (Included). Doesn't include final fabrication.
Polypropylene, Orientated Film	99.20	2.97	3.43	55.7 MJ/kg Feedstock Energy (Included).
Polypropylene, Injection Moulding	115.10	3.93	4.49	54 MJ/kg Feedstock Energy (Included). If biomass benefits are included the CO2 may reduce to 3.85 kgCO2/kg, and GWP down to 4.41 kg CO2e/kg.
Expanded Polystyrene	88.60	2.55	3.29	46.2 MJ/kg Feedstock Energy (Included)
General Purpose Polystyrene	86.40	2.71	3.43	46.3 MJ/kg Feedstock Energy (Included)
High Impact Polystyrene	87.40	2.76	3.42	46.4 MJ/kg Feedstock Energy (Included)
Thermoformed Expanded Polystyrene	109.20	3.45	4.39	49.7 MJ/kg Feedstock Energy (Included)
Polyurethane Flexible Foam	102.10	4.06	4.84	33.47 MJ/kg Feedstock Energy (Included). Poor data availability for feedstock energy
Polyurethane Rigid Foam	101.50	3.48	4.26	37.07 MJ/kg Feedstock Energy (Included). Poor data availability for feedstock energy
PVC General	77.20	2.61	3.10	28.1 MJ/kg Feedstock Energy (Included). Based on market average consumption of types of PVC in the European construction industry
PVC Pipe	67.50	2.56	3.23	24.4 MJ/kg Feedstock Energy (Included). If biomass benefits are included the CO2 may reduce to 2.51 kgCO2/kg, and GWP down to 3.23 kg CO2e/kg.
Calendered Sheet PVC	68.60	2.61	3.19	24.4 MJ/kg Feedstock Energy (Included). If biomass benefits are included the CO2 may reduce to 2.56 kgCO2/kg, and GWP down to 3.15 kg CO2e/kg.
PVC Injection Moulding	95.10	2.69	3.30	35.1 MJ/kg Feedstock Energy (Included). If biomass benefits are included the CO2 may reduce to 2.23 kgCO2/kg, and GWP down to 2.84 kg CO2e/kg.
UPVC Film	69.40	2.57	3.16	25.3 MJ/kg Feedstock Energy (Included)
Rubber				
General	91.00	2.66	2.85	40 MJ/kg Feedstock Energy (Included)
Sand				
General	0.081	0.0048	0.0051	Estimated from real UK industrial fuel consumption data
Sealants and adhesives				
Epoxide Resin	137.00	5.70	-	42.6 MJ/kg Feedstock Energy (Included). Source: www.plasticseurope.org
Mastic Sealant	62 to 200	-	-	
Melamine Resin	97.00	4.19	-	Feedstock energy 18 MJ/kg - estimated from Ref 34.
Phenol Formaldehyde	88.00	2.98	-	Feedstock energy 32 MJ/kg - estimated from Ref 34.
Urea Formaldehyde	70.00	2.76	-	Feedstock energy 18 MJ/kg - estimated from Ref 34.
Soil				
General (Rammed Soil)	0.45	0.023	0.024	
Cement stabilised soil @ 5%	0.68	0.060	0.061	Assumed 5% cement content.
Cement stabilised soil @ 8%	0.83	0.082	0.084	Assumed 8% stabiliser content (6% cement and 2% lime).
GGBS stabilised soil	0.65	0.045	0.047	Assumed 8% stabiliser content (8% GGBS and 2% lime).
Fly ash stabilised soil	0.56	0.039	0.041	Assumed 10% stabiliser content (8% fly ash and 2% lime).

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
Steel	Main data source: International Iron & Steel Institute (IISI) LCA studies (www.worldsteel.org)			
UK (EU) STEEL DATA - EU average recycled content - See material profile (and Annex on recycling methods) for usage guide				
General - UK (EU) Average Recycled Content	**20.10**	**1.37**	**1.46**	EU 3-average recycled content of 59%. Estimated from UK's consumption mixture of types of steel (excluding stainless). **All data doesn't include the final cutting of the steel products to the specified dimensions or further fabrication activities.** Estimated from World Steel Association (Worldsteel) LCA data.
Virgin	35.40	2.71	2.89	
Recycled	9.40	0.44	0.47	Could not collect strong statistics on consumption mix of recycled steel.
Bar & rod - UK (EU) Average Recycled Content	**17.40**	**1.31**	**1.40**	EU 3-average recycled content of 59%
Virgin	29.20	2.59	2.77	
Recycled	8.80	0.42	0.45	
Coil (Sheet) - UK (EU) Average Recycled Content	**18.80**	**1.30**	**1.38**	Effective recycled content because recycling route is not typical. EU 3-average recycled content of 59%
Virgin	32.80	2.58	2.74	
Recycled	Not Typical Production Route			
Coil (Sheet), Galvanised - UK (EU) Average Recycled Content	**22.60**	**1.45**	**1.54**	Effective recycled content because recycling route is not typical. EU 3-average recycled content of 59%
Virgin	40.00	2.84	3.01	
Engineering steel - Recycled	**13.10**	**0.68**	**0.72**	
Pipe- UK (EU) Average Recycled Content	**19.80**	**1.37**	**1.45**	Effective recycled content because recycling route is not typical. EU 3-average recycled content of 59%
Virgin	34.70	2.71	2.87	
Recycled	Not Typical Production Route			
Plate- UK (EU) Average Recycled Content	**25.10**	**1.55**	**1.66**	Effective recycled content because recycling route is not typical. EU 3-average recycled content of 59%
Virgin	45.40	3.05	3.27	
Recycled	Not Typical Production Route			
Section- UK (EU) Average Recycled Content	**21.50**	**1.42**	**1.53**	
Virgin	38.00	2.82	3.03	
Recycled	10.00	0.44	0.47	
Wire - Virgin	**36.00 (?)**	**2.83 (?)**	**3.02**	
Stainless	**56.70**	**6.15**		World average data from the Institute of Stainless Steel Forum (ISSF) life cycle inventory data. Selected data is for the most popular grade (304). Stainless steel does not have separate primary and recycled material production routes.
OTHER STEEL DATA - 'R.O.W' and 'World' average recycled contents - See material profile (and Annex on recycling methods) for usage guide				
General - R.O.W. Avg. Recy. Cont.	26.20	1.90	2.03	Rest of World (non-E.U.) consumption of steel. 3 year average recycled content of 35.5%.
General - World Avg. Recy. Cont.	25.30	1.82	1.95	Whole world 3 year average recycled content of 39%.
Bar & rod- R.O.W. Avg. Recy. Cont.	22.30	1.82	1.95	Comments above apply. See material profile for further information.
Bar & rod - World Avg. Recy. Cont.	21.60	1.74	1.86	
Coil - R.O.W. Avg. Recy. Cont.	24.40	1.81	1.92	
Coil - World Avg. Recy. Cont.	23.50	1.74	1.85	
Coil, Galvanised - R.O.W. Avg. Recy. Cont.	29.50	2.00	2.12	
Coil, Galvanised - World Avg. Recy. Cont.	28.50	1.92	2.03	
Pipe - R.O.W. Avg. Recy. Cont.	25.80	1.90	2.01	
Pipe - World Avg. Recy. Cont.	24.90	1.83	1.94	
Plate - R.O.W. Avg. Recy. Cont.	33.20	2.15	2.31	
Plate - World Avg. Recy. Cont.	32.00	2.06	2.21	
Section - R.O.W. Avg. Recy. Cont.	28.10	1.97	2.12	
Section - World Avg. Recy. Cont.	27.10	1.89	2.03	
Stone	Data on stone was difficult to select, with high standard deviations and data ranges.			
General	**1.26 (?)**	**0.073 (?)**	**0.079**	ICE database average (statistic), uncertain. See material profile.
Granite	**11.00**	**0.64**	**0.70**	Estimated from Ref 116.
Limestone	**1.50**	**0.087**	**0.09**	Estimated from Ref 188.
Marble	**2.00**	**0.116**	**0.13**	
Marble tile	**3.33**	**0.192**	**0.21**	Ref. 40.
Sandstone	**1.00 (?)**	**0.058 (?)**	**0.06**	Uncertain estimate based on Ref. 262.
Shale	**0.03**	**0.002**	**0.002**	
Slate	**0.1 to 1.0**	**0.006 to 0.058**	**0.007 to 0.063**	Large data range
Timber	Note: These values were difficult to estimate because timber has a high data variability. These values exclude the energy content of the wooden product (the Calorific Value (CV) from burning). See the material profile for guidance on the new data structure for embodied carbon (i.e. split into foss and bio)			
General	**10.00**	**$0.30_{fos}+0.41_{bio}$**	**$0.31_{fos}+0.41_{bio}$**	Estimated from UK consumption mixture of timber products in 2007 (Timber Trade Federation statistics). Includes 4.3 MJ bio-energy. All values do not include the CV of timber product and exclude carbon storage.
Glue Laminated timber	**12.00**	**$0.39_{fos}+0.45_{bio}$**	**$0.42_{fos}+0.45_{bio}$**	Includes 4.9 MJ bio-energy.
Hardboard	**16.00**	**$0.54_{fos}+0.51_{bio}$**	**$0.58_{fos}+0.51_{bio}$**	Hardboard is a type of fibreboard with a density above 800 kg/m3. Includes 5.6 MJ bio-energy.
Laminated Veneer Lumber	**9.50**	**$0.31_{fos}+0.32_{bio}$**	**$0.33_{fos}+0.32_{bio}$**	Ref 150. Includes 3.5 MJ bio-energy.
MDF	**11 (?)**	**$0.37_{fos}+0.35_{bio}$**	**$0.39_{fos}+0.35_{bio}$**	Wide density range (350-800 kg/m3). Includes 3.8 MJ bio-energy.
Oriented Strand Board (OSB)	**15.00**	**$0.42_{fos}+0.54_{bio}$**	**$0.45_{fos}+0.54_{bio}$**	Estimated from Refs. 103 and 150. Includes 5.9 MJ bio-energy.
Particle Board	**14.50**	**$0.52_{fos}+0.32_{bio}$**	**$0.54_{fos}+0.32_{bio}$**	Very large data range, difficult to select appropriate values. Modified from CORRIM reports. Includes 3.2 MJ bio-energy (uncertain estimate).

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
Plywood	**15.00**	**$0.42_{fos}+0.65_{bio}$**	**$0.45_{fos}+0.65_{bio}$**	Includes 7.1 MJ bio-energy.
Sawn Hardwood	**10.40**	**$0.23_{fos}+$ 0.63_{bio}**	**$0.24_{fos}+$ 0.63_{bio}**	It was difficult to select values for hardwood, the data was estimated from the CORRIM studies (Ref. 88). Includes 6.3 MJ bio-energy.
Sawn Softwood	**7.40**	**$0.19_{fos}+0.39_{bio}$**	**$0.20_{fos}+0.39_{bio}$**	Includes 4.2 MJ bio-energy.
Veneer Particleboard (Furniture)	**$23_{(fos + bio)}$**	**(?)**	**(?)**	Unknown split of fossil based and biogenic fuels.
Tin				
Tin Coated Plate (Steel)	**19.2 to 54.7**	**1.04 to 2.95**	**-**	
Tin	**250.00**	**13.50**	**14.47**	lack of modern data, large data range
Titanium				
Virgin	**361 to 745**	**19.2 to 39.6 (??)**	**20.6 to 42.5 (??)**	lack of modern data, large data range, small sample size
Recycled	**258.00**	**13.7 (??)**	**14.7 (??)**	lack of modern data, large data range, small sample size
Vinyl Flooring				
General	**68.60**	**2.61**	**3.19**	23.58 MJ/kg Feedstock Energy (Included), Same value as PVC calendered sheet. *Note: the book version of ICE contains the wrong values. These values are up to date*
Vinyl Composite Tiles (VCT)	**13.70**	-	-	Ref. 94.
Zinc				
General	**53.10**	**2.88**	**3.09**	Uncertain carbon estimates, currently estimated from typical UK industrial fuel mix. Recycled content of general Zinc 30%.
Virgin	72.00	3.90	4.18	
Recycled	9.00	0.49	0.52	

Miscellaneous (No material profiles):

	Embodied Energy - MJ	Embodied Carbon - Kg CO2		
PV Modules	**MJ/sqm**	**Kg CO2/sqm**		
Monocrystalline	**4750 (2590 to 8640)**	**242 (132 to 440)**	**-**	Embodied carbon estimated from typical UK industrial fuel mix. This is not an ideal method.
Polycrystalline	**4070 (1945 to 5660)**	**208 (99 to 289)**	**-**	
Thin Film	**1305 (775 to 1805)**	**67 (40 to 92)**	**-**	
Roads	Main data source: ICE reference number 147			
Asphalt road - Hot construction method - 40 yrs	**2,509 MJ/Sqm**	**93 KgCO2/Sqm**	**99 KgCO2/Sqm**	730 MJ/Sqm Feedstock Energy (Included). For more detailed data see reference 147. (Swedish study). The data in this report was modified to fit within the ICE framework. Includes all sub-base layers to construct a road. Sum of construction, maintenance, operation.
Construction	1,069 MJ/Sqm	30.9 KgCO2/Sqm	32.8 KgCO2/Sqm	480 MJ/Sqm Feedstock Energy (Included)
Maintenance - 40 yrs	471 MJ/Sqm	11.6 KgCO2/Sqm	12.3 KgCO2/Sqm	250 MJ/Sqm Feedstock Energy (Included)
Operation - 40 yrs	969 MJ/Sqm	50.8 KgCO2/Sqm	54.0 KgCO2/Sqm	Swedish scenario of typical road operation, includes street and traffic lights (95% of total energy), road clearing, sweeping, gritting and snow clearing.
Asphalt road - Cold construction method - 40 yrs	**3,030 MJ/Sqm**	**91 KgCO2/Sqm**	**97 KgCO2/Sqm**	1,290 MJ/kg Feedstock Energy (Included). Sum of construction, maintenance, operation.
Construction	825 MJ/Sqm	26.5 KgCO2/Sqm	28.2 KgCO2/Sqm	320 MJ/Sqm Feedstock Energy (Included)
Maintenance - 40 yrs	1,556 MJ/Sqm	13.9 KgCO2/Sqm	14.8 KgCO2/Sqm	970 MJ/Sqm Feedstock Energy (Included)
Operation - 40 yrs	969 MJ/Sqm	50.8 KgCO2/Sqm	54.0 KgCO2/Sqm	See hot rolled asphalt.
Concrete road - 40 yrs	**2,084 MJ/Sqm**	**142 KgCO2/Sqm**	-	Sum of construction, maintenance, operation.
Construction	885 MJ/Sqm	77 KgCO2/Sqm	-	
Maintenance - 40 yrs	230 MJ/Sqm	14.7 KgCO2/Sqm	-	
Operation - 40 yrs	969 MJ/Sqm	50.8 KgCO2/Sqm	-	Swedish scenario of typical road operation, includes street and traffic lights (95% of total energy), and also road clearing, sweeping, gritting and snow clearing.

Note: *The above data for roads were based on a single reference (ref 145). There were other references available but it was not possible to process the reports into useful units (per sqm). One of the other references indicates a larger difference between concrete and asphalt roads than the data above. If there is a particular interest in roads the reader is recommended to review the literature in further detail.*

Windows	MJ per Window			
1.2mx1.2m Single Glazed Timber Framed Unit	**286 (?)**	**14.6 (?)**	**-**	Embodied carbon estimated from typical UK industrial fuel mix
1.2mx1.2m Double Glazed (Air or Argon Filled):	--	--	-	--
Aluminium Framed	**5470**	**279**	-	
PVC Framed	**2150 to 2470**	**110 to 126**	-	
Aluminium -Clad Timber Framed	**950 to 1460**	**48 to 75**	-	
Timber Framed	**230 to 490**	**12 to 25**	-	
			-	
Krypton Filled Add:	**510**	**26**	-	
Xenon Filled Add:	**4500**	**229**	-	

NOTE: Not all of the data could be converted to full GHG's. It was estimated from the fuel use only (i.e. Not including any process related emissions) the full CO2e is approximately 6 percent higher than the CO2 only value of embodied carbon. This is for the average mixture of fuels used in the UK industry.