TE200A

ANALYSIS OF CURRENTLY AVAILABLE ENVIRONMENTAL PROFILES OF BUILDING PRODUCTS

FINAL

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1. EXECUTIVE SUMMARY

Environmental life cycle assessment (LCA) is a suitable tool for assessing the environmental performance of a building, a building construction or a building material by taking a systems perspective over the whole life cycle.

Accurate, consistent and relevant data is a key requirement for meaningful LCA studies which can be used in decision making processes of organisations, and for policy making. The process of collecting and providing such data is time consuming.

In New Zealand and internationally, a number of building-related LCA studies have already been conducted. This study summarises the work done in New Zealand and describes the most relevant overseas databases. The goal was to analyse the applicability of international data to New Zealand situations.

The comparison of embodied energy and results for CO_2 emissions showed that New Zealand data differ significantly from overseas data. No general trends were evident: values were higher for certain products and lower for others. The main differences are due to country-specific processes and fuel use, but also due to variations in the methodology of data collection and assessment of environmental impacts.

Currently, New Zealand data are limited to energy use and CO_2 emissions for most building products. However, an overall environmental evaluation has to consider other aspects as well. The most important environmental impact categories are acidification, eutrophication, ozone depletion, photochemical ozone creation, human toxicity and ecotoxicity. For the assessment of these additional impacts a full inventory of material and energy use of the whole life cycle is necessary.

The main building materials, where further LCA work is of special importance, are:

1. Aluminium
2. Brick
3. Cement
4. Concrete
5. Fibre cement
6. Glass
7. Gypsum board
8. Fibre glass insulation
9. Plastic
10. Steel
11. Timber

2. INTRODUCTION

Environmental life cycle assessment (LCA) provides a suitable tool for assessing the environmental performance of a building by taking a systems perspective over the whole life cycle. The approach is based on the concept of Life Cycle Thinking which integrates consumption and production strategies over a whole life cycle, so preventing a piece-meal approach. Life cycle approach avoids problem-shifting from one life cycle stage to another, from one geographic area to another, and from one environmental medium to another.

The use of the tool LCA is dependent on accurate data which is relevant and specific to the geographical region. In order to prepare comparable results, LCA studies should also be conducted to a standard methodology, as, for example, laid out in ISO Standards 14040 and 14044 (ISO 14040, 2006, ISO 14044 2006.

The process of collecting and providing such data is time consuming and requires much information. A number of studies in New Zealand, and internationally, have already been carried out in order to provide such LCA data. Therefore, the question arises as to whether international data can be used in the New Zealand context. Based on data for CO_2 emissions and embodied energy for New Zealand, the applicability of international data is considered in this report. This report is not a comprehensive assessment of LCA on New Zealand building products nor an evaluation of their impact. The main objective was to provide an initial assessment of the use of international data sources for New Zealand materials and products based on energy and CO_2 emissions. Furthermore, to make recommendations as to what materials and products should be early priorities for collation of LCA data. The project workplan is provided in Appendix 2.

3. LCA DATABASES IN NEW ZEALAND AND OVERSEAS

3.1 LCA data in New Zealand

LCA studies of building materials have been conducted in New Zealand since the late 1990s. One of the first overviews on LCA in New Zealand was prepared by Jaques (1998). Preliminary environmental profiles for steel and three common composite sheet materials were established in Jaques (2002) and (2004). Key projects related to building materials are briefly described below.

NZIA Environmental Material Comparison Charts

The NZIA Environmental Material Comparison Charts (1996) were compiled to allow designers, builders, and specifiers to make environmental assessments of common construction product groups, based on life cycle aspects. However, much of the information was qualitative; only energy was considered in a more quantitative context.

Embodied Energy and CO_2 Coefficients

Alcorn (1995, 1998, 2003) has compiled New Zealand-specific data on embodied energy and CO_2 emissions for approximately 60 different building materials. These range from aggregate (river or virgin rock), over cement, copper, to steel and timber. The study covers energy consumption and CO_2 emissions from resource extraction, transport, and processing, i.e., “cradle to gate”. Included are material inputs, energy inputs, transport, capital equipment, outputs and extra information. However, the whole life cycle is not covered because the use phase, demolition, and end-of-life were not taken into account. The basis of the inventory was the information provided by industrial organisations and individual companies on the direct process energy requirements and raw material input. Whenever the acquisition of further data would have required a greatly increased effort, the analysis was truncated and national input-output coefficients based on economic values were used. Where there were gaps, international data had to be relied on. The CO_2 emissions were calculated using the New Zealand specific CO_2 coefficients of the different fuel types. The study was first published in 1995, and has been updated several times since then. The latest published update is from 2003.

Life cycle environmental inventory of 12 low energy technologies for New Zealand houses (ZALEH)

This project is a subset of the BRANZ Ltd Zero and Low Energy Household (ZALEH) project. The objective was to provide a life-cycle based inventory of various materials and technologies in several low-energy house designs, examining the net resulting embodied and operational energy requirements and their associated CO_2 emissions only. This study has yet to be completed and results can therefore not be taken into account in this study.

3.2 LCA data overseas

Over the last 15 years, many LCA studies have been undertaken on building materials internationally. Rather than undertaking a comprehensive review of all data and information, this study focused on comparing New Zealand information to some of the world's major LCA databases on building materials and systems. The ones considered for this study were: GaBi (IKP/PE 2002), SimaPro (Pre 2006), a German study "Ganzheitliche Bilanzierung" (Corradini et al. 1999), BRE (BRE 2004) and Athena (Athena 2002). These are described in more detail below.

GaBi (Germany)

GaBi is professional LCA software for the analysis and optimisation of complex processes and product systems. GaBi is a joint development of IKP, University of Stuttgart, and PE Europe GmbH since 1992. A distinctive feature is the visualisation of processes, allowing a quick overview of material, energy, or cost flows, all shown as proportional to quantity of inputs. The GaBi database is well-structured and transparent, with a database on building materials. Most inventories are average German industry data collected by PE Europe between 1996 and 2004. The data is generally regarded to be of high quality. The documentation describes the production process, applied boundary conditions, allocation rules etc. for each product. The database is compliant with the ISO Standards 14040-43. The tool offers various impact assessment methods for all relevant environmental impact categories. For the purposes of this study, GaBi version 4 was used.

SimaPro (Netherlands)

SimaPro (**S**ystem for **I**ntegrated Environ**m**ental **A**ssessment of **Pro**ducts) developed by the Pré Consultants in the Netherlands was one of the first LCA software tools. The tool was first released in 1990 and since then has been sold all over the world. It helps to analyse and model products and services in a systematic and transparent way, following the framework of ISO 14040-43. Many databases with inventory data are integrated or are available in the current version SimaPro 6.0, such as ecoinvent (ecoinvent 2005), ETH-Esu 96 (Frischknecht and Jungbluth 2004), BUWAL (SRU 1998) and others with specific Dutch and US data. The tool offers several impact assessment methods for all relevant impact categories. In this study, the demo of SimaPro 6.0 was used.

“Ganzheitliche Bilanzierung von Grundstoffen und Halbzeugen“ [Life Cycle Assessment of basic materials and semi-finished products]

This study is the result of a German research project supported by the Bavarian Research Fund. The aim was to provide up-to-date and harmonised inventory data for building materials based mostly on German sources and own collection (Corradini et al. 1999). The study describes the most important building materials and their production process in detail. The data are limited to the process-aggregated cumulated energy demand and basic emissions (CO_2, CO, NOx, SO_2, CH_4, NMVOC, N_2O, dust). The report is available on the internet (German language).

BRE (U.K.)

The Building Research Establishment in the United Kingdom developed environmental profiles for various building products, based on UK industry data. The BRE methodology complies with the ISO 14040-43 standards. The key indicators are climate change, acidification, ozone depletion, consumption of minerals and water, ecotoxicity, human toxicity and waste disposal. Environmental results can be aggregated to a single Ecopoint score, where 100 Ecopoints equal the impacts caused by one person in the UK for one year. The data are integrated into the software tool Envest 2. In this study, data available on the website of BRE were used.

Athena Environmental Impact Estimator (Canada/U.S.)

Athena is user-friendly software for the LCA of buildings developed by the Athena Sustainable Materials Institute in Canada. The tool allows architects and engineers to assess and compare building designs and material choices at an early stage. The conceptual building design is easily entered using preset building assembly dialogues. The database contains North American (primarily Canadian) inventory data on structural assemblies and building envelope materials. Operating energy calculated elsewhere can be converted to environmental impacts taking into account the upstream effects. The maintenance of building assemblies is also considered assuming a user-defined building lifetime. The results are presented by life cycle stage or by assembly type in terms of primary energy use, global warming potential, solid waste emissions, pollutants to air and water, and natural resource use.

Australian Life Cycle Inventory

The Life Cycle Inventory Data Research Program aims at developing detailed inventory resources for Australia. The inventories on building products include plastics, aluminium, steel, timber and concrete. Data are published in spreadsheets but they are also available in SimaPro. However, since the reports are not finalised yet and cannot be quoted, data were not included in this analysis.

4. COMPARISON OF DATA SOURCES

The New Zealand and overseas data on the embodied energy and CO_2 emissions of basic building materials are compared in Table 1 (see Appendix 1). Table 2 shows the New Zealand data by Alcorn as a percentage of overseas data. New Zealand data, excluding some extreme values, are in a range between 20 and 350 % of the overseas information. The comparison of data has shown that there is no general tendency for New Zealand data to be lower or higher than data from overseas. For some building materials, such as aluminium and timber, the New Zealand data are lower; for others such as cement, gypsum board or steel the results are higher.

Differences are due to country-specific processes and differences in transport distances, but also due to variations in the methodology of the inventory analysis, i.e., data collection and underlying assumption as well as differences in the assessment of the environmental impacts. These differences are described below and demonstrated for the product groups of metals and timber.

4.1 Country/region related differences

Country-specific differences are mainly due to different fuel types and electricity production mixes. Whereas 62 % of New Zealand electricity is generated by hydro power, the German electricity mix is dominated by nuclear power, lignite and hard coal. Hydro power accounts for only 4 %.

Transport distances are also different in the geographic locations. A number of raw materials have to be shipped to New Zealand from overseas. The transport-related emissions and energy requirements result in different environmental life cycle impacts of the products.

4.2 Differences in inventory analysis

The inventory data in the databases are mostly based on detailed process analyses and are average industry data for a given region or country. Alcorn used hybrid analysis, which is a combination of process analysis and economical input-output analysis.

Quality, representativeness, geographical applicability, time horizons and system boundaries of data are often inhomogeneous even within one database. Data are usually of second order, i.e., the material and energy flows related to the extraction of raw materials and the manufacturing of the product are considered. However, Alcorn, and in some instances SimaPro, account for capital goods and infrastructure as well. According to ISO 14040, capital goods should generally be excluded from LCA studies.

Although every effort has been made to find comparable products for the analysis, it was not always possible. For polyvinyl chloride, for example, Alcorn includes the process of extrusion, while GaBi inventory ends at the granulate stage.

4.3 Impact assessment categories

New Zealand data by Alcorn are limited to embodied energy and carbon dioxide emissions. Most of the overseas databases contain the full inventory of the processes and the user can choose from a set of impact assessment methods and categories. The Dutch CML 2001 baseline methodology (Guinee 2002), which is the most accepted and widespread assessment method, recommends the categories global warming, acidification, eutrophication, ozone depletion, photo-oxidant formation, as well as human toxicity and ecotoxicity. Energy use, which is not included in CML, is usually assessed with the method of Cumulative Energy Demand (CED).

Energy use

Cumulative Energy Demand recommends that it is necessary to distinguish between non-renewable (fossil, nuclear) and renewable (hydro, solar, geothermal, biomass) energy sources. While the efficient use of all energy resources is an overall goal, the depletion of finite abiotic resources is an especially important issue. In GaBi and SimaPro the embodied energy is split into renewable and non-renewable resources and the total of all greenhouse gas emissions is given, not just the CO_2 emissions. At the moment, only the total energy figures are available for New Zealand building products. The disaggregation of these data, as in GaBi and SimaPro, would be beneficial.

Global Warming Potential vs. CO_2 emissions

Anthropogenic emissions of greenhouse gases enhance the natural greenhouse effect and are being attributed to global warming. The consequences might involve global climate change, the shift of vegetation zones and of precipitation distribution, and the rise of the sea level due to the melting ice caps. Although carbon dioxide is one of the most important greenhouse gases, other gases such as methane, CFCs and HCFCs also contribute to global warming. Their effect is expressed in terms of CO_2-equivalents. Methane, for example, has a weighting of 23, in other words 1 kg of methane contributes 23 times as much to global warming as 1 kg CO_2.

The analysis of datasets for building materials in GaBi and SimaPro has shown that the difference between the CO_2 emissions and the total global warming potential is on average 5-10 %, but it can be as high as 25-35 % as, for example, with aluminium. This shows that it is important to take other greenhouse gases into account and not to limit the results to CO_2 emissions.

Other impact categories

Many environmental impacts, such as global warming, acidification and photochemical ozone creation are closely correlated with the energy demand, which makes CED suitable as a screening indicator in LCA. However, the ratio between energy use and environmental impact categories is different for every product; there is no generic factor for calculating the environmental impacts based on the figure for the aggregated energy use. Figure 1 shows an example of four insulation materials based on GaBi data. The impact assessment results of expanded polystyrene are set to 100%. In the category of energy use, the highest values are for polyurethane foam (PUR) and the lowest for rock wool. This is generally valid for every impact category. However, the ratios are very different. While PUR is 44% higher than the reference material in energy use, it is almost 200% higher in eutrophication but only 5% higher in ozone depletion. The results for glass wool are generally lower than for expanded polystyrene, but for eutrophication potential there is a greater environmental impact for glass wool.

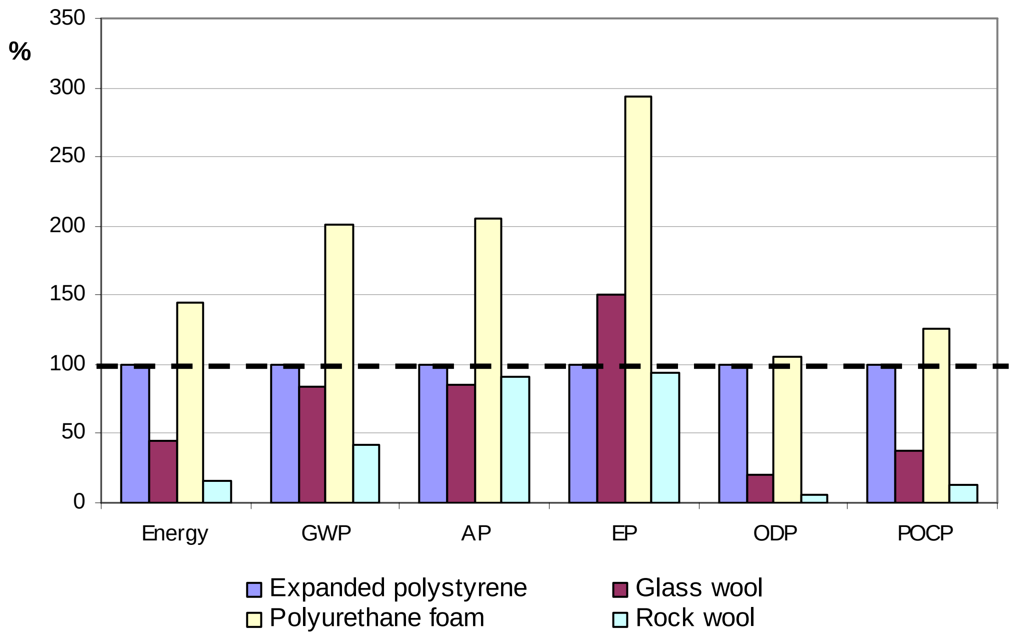

Figure 1 Ratio of impact assessment results for four insulation materials

The comparison of these four products with regard to energy use and five different environmental impact categories shows that embodied energy and CO_2 emissions alone do not describe all the environmental impacts related to a product. To get an overall picture, other impact categories, such as acidification, eutrophication, ozone depletion and photochemical ozone creation, have to be considered as well.

4.4 Metals

The production of aluminium is especially energy intensive. In particular, the process of electrolysis requires high amounts of electrical energy. The electricity mix of a country has therefore great influence on the results. The primary energy and emissions related to high use of hydro, for instance, are generally less than if fossil fuels are dominant in the mix. In New Zealand, more than 60% of the electricity comes from hydro power (Dang 2005). The SimaPro model is based on the Swiss imports, where aluminium comes from 60% European and 40% Canadian (100% hydro power) production. In GaBi, the renewable ratio is considerably less.

Recycling, which is a common process for most metals, is another important issue when comparing values. Different assumptions here can lead to very different results. On the one hand, the actual recycled content differs from country to country and, on the other hand, several methods exist for accounting for the use of scrap in metal production. The two basic approaches are the cut-off approach and the value-corrected substitution. The more common cut-off approach uses a certain mixture of primary and secondary metal, usually based on actual statistical data. The environmental impacts are highly dependent on the assumed ratios. This is probably one of the reasons for the differences in copper values, for example. The Alcorn data relate to virgin copper, while in GaBi and SimaPro a default secondary quota of 60% and 40% is used, respectively. At the end of the useful lifetime, the product leaves the system as waste without an "ecological rucksack" and it is a "free" input for the subsequent recycling process. However, the impacts caused by the collection, cleaning and melting of the scrap are usually included.

The other approach, the so-called value-corrected substitution, takes into account the future recycling potential of a product. This is the ideal recycling scenario or the highest technically feasible recycling rate. In GaBi, a chosen recycling potential can be added to certain processes. The benefits of recycling are considered in terms of avoided production.

4.5 Timber

Growing trees remove carbon dioxide from the atmosphere and convert it, together with water and elements from the soil, through the process of photosynthesis to biomass. The required energy for the process is delivered by the sun. Inversely, due to natural decay and deterioration as well as combustion, the stored carbon is released to the atmosphere while the arising thermal energy can be utilised.

While Alcorn, SimaPro and BRE exclude the solar energy input from the embodied energy values, GaBi and the study "Ganzheitliche Bilanzierung" calculate it as equal to the calorific value of wood.

Negative CO_2 emissions mean that the emissions corresponding to the raw material extraction and the manufacturing do not exceed the amount of carbon dioxide removed from the atmosphere. CO_2 sequestration is not taken into account in GaBi, Ganzheitliche Bilanzierung and Athena. The original data given in these databases have been corrected to produce comparable results. The CO_2 absorption was assumed to be 1.835 kg/kg of wood. This approach is valid as long as the analysis goes "from cradle to gate", i.e., ends at manufacturing. At the end of life the carbon storage is extended if the wood is reused or landfilled. With the combustion of wood, carbon is released into the atmosphere again, although emitting only the same amount of carbon as growing trees had removed from the atmosphere.

5. COMMON BUILDING MATERIALS IN NEW ZEALAND

A number of studies were reviewed to define the most typical building constructions in New Zealand houses and to assess the market share of different building materials. The BRANZ Materials Survey 2004 has data on new stand-alone houses. In the 2005 House Condition Survey from BRANZ (Clark *et al.* 2005) a sample of 565 houses, representative for the New Zealand housing stock regarding their age, location and size, were analysed. Mithraratne (2001) studied the offer of 12 construction firms in Auckland in order to determine the choice customers are most commonly offered.

Foundation, floors and decks

The foundation and ground floor construction types are usually related. Many New Zealand houses have timber/concrete pile foundation and timber framed suspended particleboard floor (Mithraratne 2001). An aluminium perforated foil insulation is required to comply with the standards. Over the last 20 years, concrete slab floors and footings have become more and more common. For deckings, radiata pine and hardwood planks are prevalent, having together a share of about 70 % (BRANZ 2004).

Walls

According to Page (1999), light timber frame walls have a market share of 95%. Other wall constructions include steel framing and concrete wall panels. Less than 30% of the existing housing stock has wall insulation (Clark *et al.* 2005) but insulation is now required in new houses. The most common insulation material for houses is fibreglass. About half of the new houses have clay brick wall cladding (BRANZ 2004), followed by coated polystyrene, fibre cement and timber weatherboard. In the sample of Clark *et al.* (2005) 50% had weatherboard cladding, but brick veneer and fibre cement were also significant.

Roofs

Pitched roofs are usually built with timber trusses or timber rafters and beams. Steel constructions represent a small proportion only. Increasingly older houses now also have ceiling insulation. The typical material is fibreglass. Metal – prepainted corrugated steel, metal tiles, steel profiles – is the prevalent cladding material, while concrete tiles have a market share of around 25%.

Windows

Of new houses, 99% have aluminium window frames, typically with single glazing (Mithraratne 2001). According to the Building Code, double glazing is now required for climate zone three, South Island and Central North Island (NZS 4218:2004).

LCA data should not only be available for the materials with the currently highest market share, but also for materials which are on offer and for possible substitutes.

6. CONCLUSIONS

In New Zealand, the most significant and comprehensive LCA-related work on building products was undertaken by Alcorn. The embodied energy and CO_2 emissions of about 60 building materials were compiled using a mixture of industry and statistical data. Worldwide, a lot of research has been done in this area and many databases exist. The most comprehensive databases contain information on the resource use and all types of emissions, and evaluate the environmental impact in a range of different impact categories.

This study compared the New Zealand and overseas data on embodied energy and CO_2 emissions of building products. New Zealand values were found to be in a range between 20% and 350% of the overseas values. No general tendency could be found: New Zealand data were higher for certain products and lower for others. Country-specific differences in production process, or in the electricity mix, for example, can be a reason. Other differences in methodology, boundary conditions and assumptions were also identified. Overseas data can therefore not easily be used in a New Zealand context. A detailed analysis of the data and the applicability would have to be made on a case by case basis, taking into account the findings of this report as well as system boundaries, assumptions and the methodology used in the respective studies. In order to develop LCA calculations for buildings in New Zealand, based on a consistent datasets, New Zealand specific LCA data for building materials needs to be developed.

Energy and CO_2 emissions are useful indicators if LCA is used in decision-making. However, for an overall environmental evaluation other aspects and other environmental impact categories need to be considered as well. The most important categories are acidification, eutrophication, ozone depletion, photochemical ozone creation, and human toxicity and ecotoxicity. Although some emissions are directly linked to energy use, the exact contribution of a product to the categories cannot be calculated based on the energy use alone. A full inventory and impact assessment is necessary to be able to evaluate the environmental performance.

Based on the typical building constructions of new and existing New Zealand houses, the main building materials, where further LCA work would be of special importance, are:

1. Aluminium
2. Brick
3. Cement
4. Concrete
5. Fibre cement
6. Glass
7. Gypsum board
8. Fibre glass insulation
9. Plastic
10. Steel
11. Timber

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APPENDIX 1. COMPARISON OF NEW ZEALAND AND OVERSEAS DATA

Table 1 Comparison of New Zealand and overseas data on embodied energy and CO_2 emissions of building materials

Database	Alcorn		GaBi					Simapro					Ganzheitliche Bilanzierung		BRE		Athena		AVERAGE	
	Embodied energy (MJ/kg)	CO_2 emissions (kg/kg)	Energy non-renewable (MJ/kg)	Energy renewable (MJ/kg)	Total energy (MJ/kg)	GWP (CO_2-eq)	CO_2 emissions (kg/kg)	Energy non-renewable (MJ/kg)	Energy renewable (MJ/kg)	Total energy (MJ/kg)	GWP (CO_2-eq)	CO_2 emissions (kg/kg)	Cumulated Energy Demand (MJ/kg)	CO_2 emissions (kg/kg)	Embodied energy (MJ/kg)	GWP (CO_2-eq)	Embodied energy (MJ/kg)	CO_2 emissions (kg/kg)	Embodied energy (MJ/kg)	CO_2 emissions (kg/kg)
Aggregate, general	0.04	0.002	0.03	0.00	0.03	0.002	0.002	0.02	0.00	0.02	0.001	0.001							0.03	0.002
Aluminium, virgin	191.55	8.000	199.31	28.50	227.81	16.821	12.741	129.00	47.50	176.50	10.600	7.640							198.62	9.460
Alu, virgin, extruded	201.74	8.354	206.72	33.06	239.78	17.389	13.182												220.76	10.768
Alu, virgin, extruded, anodised	226.38	9.359	333.89	40.75	374.64	25.542	20.546												300.51	14.953
Alu, recycled, extruded, anodised	23.83	0.886	146.04	10.79	156.83	9.612	8.386												90.33	4.636
Alu, recycled, extruded	14.56	0.721	20.16	3.41	23.57	1.554	1.021												19.07	0.871
Bitumen, feedstock	2.40	0.171	45.63	0.01	45.64	0.373	0.305	49.36	0.08	49.43	0.530	0.434							32.49	0.304
Brick	2.70	0.138	2.99	0.02	3.01	0.189	0.178	6.89	0.08	6.98	0.369	0.350	3.13	0.175			4.58	0.232	4.08	0.215
Cement, average	6.16	0.994	4.32	0.12	4.43	0.722	0.710	4.79	0.08	4.87	0.990	0.964	4.29	0.890			4.57	0.776	4.86	0.867
Concrete ready mix, 17.5 MPa	0.86	0.114	0.73	0.01	0.74	0.107	0.106	0.85	0.02	0.86	0.135	0.131	0.66	0.118	0.61	0.075	0.70	0.091	0.74	0.106
Concrete ready mix, 30 MPa	1.17	0.159	0.84	0.02	0.86	0.136	0.133										0.94	0.128	0.99	0.140
Concrete roofing tile	0.81		1.28	0.03	1.31	0.186	0.179												1.06	0.179
Copper, virgin, sheet	97.64	7.738	45.23	4.90	50.13	3.211	3.019	97.70	3.49	101.19	5.470	5.210							82.99	5.322
Fibre cement board	9.36	0.629	15.77	0.12	15.88	1.258	1.207												12.62	0.918
Glass, float, tint	15.89	1.735	13.35	0.05	13.40	1.355	1.286	13.31	0.11	13.41	1.020	0.968	14.36	1.184					14.27	1.293
Gypsum plaster board	7.37	0.421	3.89	0.29	4.18	0.176	0.167						3.46	0.155			3.16	0.161	4.54	0.226
Insulation, polystyrene	58.36	2.495	92.51	0.17	92.68	2.863	2.668												75.52	2.582
Insulation, fibreglass	32.07	0.770	39.32	2.22	41.55	2.396	2.255						16.45	1.011	31.00	1.100			30.27	1.284
Plastic, HDPE	50.97	3.447	73.97	0.39	74.36	1.278	0.940	79.33	1.03	80.36	1.870	1.750							68.56	2.046
Plastic, LDPE	50.97	3.539	80.80	0.54	81.34	1.588	1.250	80.50	1.39	81.89	2.060	1.940							71.40	2.243
Plastic, PVC, extruded	60.86	4.349	58.90	0.35	59.25	2.332	2.177	55.70	0.95	56.65	2.110	1.950							58.92	2.825
Sand	0.10	0.007	0.03	0.00	0.03	0.002	0.002	0.15	0.00	0.15	0.010	0.010	0.04	0.003					0.08	0.005
Steel, virgin, general	31.31	1.242	22.52	0.39	22.91	1.457	1.312												27.11	1.277
Steel, stainless, average	74.82	5.457	53.79	6.29	60.08	4.838	4.624												67.45	5.040
Timber, air dried, roughsawn, untreated	2.81	-1.665	0.53	17.22	17.75	0.034	-1.802						7.18	-1.783					9.25	-1.750
Timber, kiln dried, gas fired, dressed	9.52	-1.349	1.35	21.14	22.49	0.509	-1.329	1.68	0.09	1.78	-1.900	-1.910	20.83	-1.392	5.00	-1.200	5.82	-1.318	10.91	-1.416
Timber glulam	13.64	-1.141	7.85	30.42	38.27	1.802	-0.053	9.07	0.49	9.56	-2.410	-2.440	27.76	-1.045				-1.178	22.31	-1.171

Database	Alcorn as a percentage of GaBi		Alcorn as a percentage of SimaPro		Alcorn as a percentage of Ganzheitliche		Alcorn as a percentage of BRE		Alcorn as a percentage of Athena	
	Embodied energy (%)	CO_2 emissions (%)	Embodied energy (%)	CO_2 emissions (%)	Embodied energy (%)	CO_2 emissions (%)	Embodied energy (%)	CO_2 emissions (%)	Embodied energy (%)	CO_2 emissions (%)
Aggregate, general	**127**	114	**193**	**196**						
Aluminium, virgin	84	**63**	109	105						
Alu, virgin, extruded	84	**63**								
Alu, virgin, extruded, anodised	**60**	**46**								
Alu, recycled, extruded, anodised	**15**	**11**								
Alu, recycled, extruded	**62**	**71**								
Bitumen, feedstock	**5**	**56**	**5**	**39**						
Brick	90	**77**	**39**	**39**	86	79			**59**	**59**
Cement, average	**139**	**140**	**126**	103	**144**	112			**135**	**128**
Concrete ready mix, 17.5 MPa	115	108	100	87	**131**	97	**141**	**152**	**123**	**125**
Concrete ready mix, 30 MPa	**136**	119							**125**	**124**
Concrete roofing tile	**62**									
Copper, virgin, sheet	**195**	**256**	96	**149**						
Fibre cement board	59	52								
Glass, float, tint	119	**135**	118	**179**	111	**147**				
Gypsum plaster board	**176**	**252**			**213**	**271**			**233**	**261**
Insulation, polystyrene	**63**	94								
Insulation, fibreglass	**77**	**34**			**195**	76	103	**70**		
Plastic, HDPE	**69**	**367**	**63**	197						
Plastic, LDPE	**63**	**283**	**62**	182						
Plastic, PVC, extruded	103	**200**	107	**223**						
Sand	**293**	**334**	**66**	**71**	**227**	**229**				
Steel, virgin, general	**137**	95								
Steel, stainless, average	**125**	118								
Timber, air dried, roughsawn, untreated	**16**	92			**39**	93				
Timber, kiln dried, gas fired, dressed	**42**	102	**536**	**71**	**46**	97	**190**	112	**164**	102
Timber glulam	**36**	**2160**	**143**	**47**	**49**	109				97

Table 2 New Zealand embodied energy and CO_2 emissions of building materials as a percentage of overseas data (Differences exceeding 20 % are in bold)