Life Cycle Assessment: Adopting and adapting overseas LCA data and methodologies for building materials in New Zealand

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EXECUTIVE SUMMARY

Objective

The objective of this research was to develop datasets for New Zealand building materials for use in research, policy analysis and building code development. The datasets were developed using Life Cycle Assessment (LCA) studies of timber and other building materials, by combining, updating and extending existing overseas data and New Zealand information.

Key Results

Material (kg)	Energy renewable [MJ]	Energy non renewable [MJ]	GWP (Global Warming Potential) [kg CO_2 Equiv.]	AP (Acidification Potential) [kg SO_2 Equiv.]	EP (Eutrophication Potential) [kg PO_4^{3-} Equiv.]	POCP (Photo-chemical Oxidant Formation Potential) [kg C_2H_2 Equiv.]
Concrete, 17.5 MPa	0.05	0.61	0.102	0.00021	0.000035	0.000019
Concrete, 40 MPa	0.08	0.92	0.158	0.00031	0.000051	0.000028
Pre-Cast Concrete	0.15	1.1	0.170	0.00034	0.000053	0.000032
Concrete tiles	0.27	2.4	0.263	0.00061	0.000072	0.000052
Reinforcing steel	2.9	5.5	0.449	0.00125	0.000064	0.000165
Structural Steel	0.88	24	1.802	0.00534	0.000471	0.000805
Steel Sheet	2.0	31	2.284	0.00652	0.000580	0.000955
Paint, water based	1.0	44	2.077	0.03687	0.000522	0.017068
Fired clay brick	0.36	2.2	0.246	0.00035	0.000030	0.000022
Glass fibre insulation	7.8	21.5	1.660	0.00540	0.000575	0.000952
PE membrane (building wrap)	3.1	83	2.368	0.00731	0.000547	0.001524
Fibre Cement Sheet	6.8	8.4	0.697	0.00246	0.000191	0.000137
Aluminium, extruded	77	124	11.312	0.05388	0.001897	0.005081
Glass Window (double-glazed, aluminium frame)	1643	7786	598.878	2.62658	0.158462	0.250040
GIB ® plasterboard	5.1	0.5	0.340	0.00099	0.000120	0.000090
Sawn timber, kiln dried (10%) (Emissions only)	8.6	1.9	0.154	0.00174	0.000227	0.000229
Sawn timber, kiln dried (10%) (CO_2 uptake)			- 1.684			
Particle Board (Emissions only)	4.1	5.0	0.279	0.00092	0.000184	0.000320
Particle Board (CO_2 uptake)			- 1.417			
Plywood (Emissions only)	8.1	7.0	0.210	0.00211	0.000295	0.000245
Plywood (CO_2 uptake)			- 1.385			

Application of Results

The results of this project, in combination with the greenhouse gas footprinting research for the forestry sector, can be used in research projects around the environmental performance of different building types. The results can also be used to research building systems and the relationship of embodied environmental impacts vs. impacts due to the use of a building.

This project has identified a problem in the significant variation between New Zealand and European manufacturing, and the resulting data differences. This has highlighted the difficulty of using data from one country or region in another country that does not share common manufacturing resources, specifically Europe and New Zealand.

A more comprehensive dataset built from the ground up, using the specific detail of New Zealand data, supplemented by international data, would provide more robust results for use in other research on the environmental impacts of buildings. Because of the essentially inherent regional divergence and consequent difficulty in combining the New Zealand and international data, the combined data presented in this work needs to be used with caution.

Further Work

Only key building materials have been covered in this report. Further work on energy carriers, such as coal, natural gas and diesel that are specific for New Zealand would complement this study and extend the applicability of Life Cycle Assessment studies in New Zealand.

The inherent difficulty of combining building material manufacturing, and environmental, data from another manufacturing region would ideally be overcome with a comprehensive collection and analysis of New Zealand specific data.

In the long term, the development of a comprehensive New Zealand Life Cycle Inventory database (which also would include data from other sectors such as transport and energy) would be ideal. One possible way of progressing towards this would be to align methodologies and database structure with the current Australian life cycle inventory initiative (AusLCI). This could contribute to a dataset with a predominance of New Zealand data, appropriate to the balance of local manufacture and internationally sourced materials.

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Glossary

Life Cycle Assessment – ISO 14040 defines LCA as:
"… a technique for assessing the environmental aspects and potential impacts associated with a product, by

- *compiling an inventory of relevant inputs and outputs of a product system;*
- *evaluating the potential environmental impacts associated with those inputs and outputs;*
- *interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.*

LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences."

Life Cycle Inventory – Life Cycle Inventory involves data collection and modelling of the product system, as well as description and verification of data. This encompasses all data related to environmental (e.g. CO_2) and technical (e.g. intermediate chemicals) quantities for all relevant and within-study-boundaries unit processes that comprise the product system. The collected data must be related to the functional unit defined in the goal and scope definition. The result of the inventory is an LCI which provides information about all inputs and outputs in the form of elementary flows to and from the environment from all the unit processes involved in the study. The inventory analysis involves the actual collection of data and the calculation procedures. The relevant inputs and outputs of the analysed product system are quantified and produced as a table. (ISO 14041)

Environmental Profile - Environmental Profiles allow designers to demand reliable and comparable environmental information about competing building materials, and gives suppliers the opportunity to present credible environmental information about their products. This means that designers can have confidence in the "level playing field" status of Environmental Profiles for every material type. The Environmental Profiles Methodology is a standardised method of identifying and assessing the environmental effects associated with building materials over their life cycle - that is their extraction, processing, use and maintenance, and their eventual disposal. It establishes a set of common rules and guidelines for applying Life Cycle Assessment (LCA) to construction products, to produce Environmental Profiles.

Environmental Product Declaration - The purpose of an Environmental Product Declaration (EPD) is to provide easily accessible, quality-assured and comparable information regarding environmental performance of products. An EPD presents quantified environmental data for a product based on information from a life cycle assessment (LCA) according to the ISO-standards for LCA. The purpose of EPD in the construction sector is to provide the basis for assessing buildings and identifying those, which cause less stress to the environment. This is accomplished through the communication of verifiable accurate, comprehensive environmental information for the products and their applications, thereby supporting scientifically based, fair choices and stimulating the potential for market-driven continuous environmental improvement.

An EPD is typically information which is voluntarily developed and is valid for a specified period. It must be certified by an independent authority. An EPD typically has three parts – a product or company description, details on environmental performance and details of the accreditation organization.

Functional unit - The functional unit defines the quantification of the identified functions or performance characteristics of the product. The primary purpose of the functional unit is to provide a reference by which, for a building product or service, the material flows (input and output data) of an LCA and the additional information are normalised.

Reference to the functional unit is one of the requirements for the comparability of LCA data. The functional unit, used as the denominator, provides the basis for the addition of material flows and environmental impacts for each of the life cycle stages of the building product or service.

The functional unit of a building product is based on:

- The quantified, relevant functional use or performance characteristics of the construction product when integrated into a building, taking into account the functional equivalent of the building;
- The product's service life under defined in-use conditions.

System boundary - The system boundaries determine which unit processes are included in the LCA study. Defining system boundaries is partly based on a subjective choice, made during the scope phase when the boundaries are initially set. By way of an example, boundaries between the technological system and nature can be set in an LCA. A life cycle usually begins at the extraction point of raw materials and energy carriers from nature. Final stages normally include waste generation and/or heat production.

Allocation – Allocation is the partitioning of the input or output flows of a unit process to the product system under study. In many processes more than one product is produced (joint production). In such cases it is necessary to divide the environmental impacts from the process between the products. This is not a straightforward process, but with help from allocation or system expansion it can be done. The choice between the two methods can have huge impacts on the result of the LCA. The ISO 14040 –series suggest using system expansion whenever possible, and where it is not possible allocation can be used instead.

Allocation of environmental impacts between products and co-products can for example be performed from an economic or mass point of view. Allocation is a division of the environmental impacts according to how much the products cost/weigh. The principles behind the allocation in a specific project should be presented each time an LCA is conducted.

Input/Output – In LCA methodology **Input** is defined as materials or resources used in a process, e.g. electricity, sand or water and **Output** is a product, material or energy which leaves a unit process, e.g. cement, particle board.

Foreground and Background Data – An important element in LCA practice is the distinction that has been made between **foreground and background data.** The foreground system refers to the system of primary concern. The background system delivers energy and materials to the foreground system as aggregated data sets in which individual plants and operations are not identified. The selection of foreground or background data decides if either marginal or average data are to be used.

Primary energy - Primary energy consumption is strictly speaking not an environmental impact category, but part of the inventory analysis. The primary energy is usually expressed as MJ per functional unit and includes feedstock energy, process energy, and production and delivery energy.

Global warming - Increasing amounts of greenhouse gases, such as carbon dioxide or methane, enhance the natural greenhouse effect and lead to an increase in global temperature. During the 20th century, the average global temperature has increased by about 0.6°C due to the enhanced greenhouse effect.

Acidification – Acidification refers to acid deposition from the atmosphere, mainly in the form of rain. Emissions of SO_2 and NOx can result in strong and damaging acids. Although there is currently no evidence of acid rain in New Zealand (MfE 2001), SO_2 and NOx emissions are closely monitored and regarded as an important issue in New Zealand.

Eutrophication – Eutrophication occurs when there is an increase in the concentration of nutrients in a body of water or soil, occurring both naturally and as a result of human activity. It may be caused by the run-off of synthetic fertilisers from agricultural land, or by the input of sewage or animal waste. It leads to a reduction in species diversity as well as changes in species composition, often accompanied by massive growth of dominant species. In addition, the increased production of dead biomass may lead to depletion of oxygen in the water or soil since its degradation consumes oxygen. This contributes to changes in species composition and death of organisms.

Photochemical Ozone Creation Potential (POCP) – POCP is an indicator of the ability of a Volatile Organic Compounds (VOC) to contribute to photochemical ozone formation. It is a measure of the reactivity of an organic compound with hydroxyl radicals and subsequent formation of ozone. As VOCs vary in their reactivity they therefore contribute differently to the formation of ozone. POCP is a basic measure to compare reactivities of volatile compounds.

Ozone depletion - The ozone layer in the stratosphere (10-50 km above Earth) absorbs 95-99 % of the sun's ultraviolet radiation. This radiation is harmful and sometimes lethal to wildlife, crops, and vegetation, and can cause fatal skin cancer, cataracts, and immune system damage in humans. The ozone layer therefore is crucial for any life on earth. The natural seasonal Antarctic 'ozone hole' has been enlarging since the early 1980s. On a global scale, the decline of ozone in the stratosphere recently slowed. Ozone depletion is mainly caused by CFCs which are used in aerosols, air conditioning, and refrigerators.

1 Introduction and Objective

The goal of this research is to develop datasets for New Zealand building materials for use in research, policy analysis and building code development. The datasets were developed using Life Cycle Assessment (LCA) studies of timber and other building materials, by combining, updating and extending existing overseas data and New Zealand information.

The outcome of this research project is a New Zealand specific dataset for relevant building materials which can be used in national as well as international research projects. The results of this project, in combination with the greenhouse gas footprinting research for the forestry sector, lay the basis for comparisons of datasets, and potentiate the fair comparisons of different building types.

Life Cycle Assessment (LCA) has been recognised by Government, Industry, research organisations and non-governmental organisations as a key tool to identify the potential environmental impacts of products and services. Accurate LCA studies require robust and detailed information on the environmental performance of key inputs. For a building, this includes the specific materials used, such as timber, steel, concrete, or plasterboard. Current suggestions around the potential inclusion of limits pertaining to carbon dioxide emissions and embodied energy in future iterations of the New Zealand Building Code clearly demonstrates the need for reliable data for building materials.

Data for embodied energy and carbon dioxide emissions of building materials used in New Zealand needs to be updated and extended to include other greenhouse gas emissions, in order to be in line with the work that is underway for the primary industry sectors. A common methodology across all sectors is necessary, due to the close connection between the sectors, e.g., production of timber based building materials and the forestry sector.

International databases for Life Cycle Assessment studies exist and provide comprehensive information on all green house gas emissions, detailed energy information, and information on other environmental impacts, such as ozone depletion. However, these international databases do not take the New Zealand specific context, such as the electricity mix, into account.

This research uses an internationally accepted database (the GaBi LCA database based on German/European data) and uses the data contained as a basis for the development of New Zealand specific datasets. The research identifies environmental hotspots (which are key processes that cause the highest impacts on the environment) in relevant building material processes. Focusing on the areas of most impact and updating/replacing information in the overseas database with New Zealand specific information allows the development of a strong dataset for New Zealand building materials.

2 International Standards and Methodologies – in effect and under development

The methodologies used for the development of the datasets in this project are based on the ISO standards for LCA (ISO 14040 and 14044) which provide a generic framework for LCA studies.

A more specific standard for building materials is currently under development in the EU as part of the Integrated Products Policy (IPP) of the EU: "Sustainability of construction works — Environmental product declarations — Product category rules".

A brief introduction to those standards and their context is provided in this section.

Another standard recently published in the UK is the PAS 2050:2008 (BSI, 2008). This focuses on the calculation of a carbon footprint only, without taking other environmental impacts into account. It is briefly introduced, but is not the basis for the calculations in this report.

- **ISO standards 14040 and 14044: Life Cycle Assessment**

The methodology used in this work is based on international standards for Life Cycle Assessment principles and methodologies, i.e., ISO 14040[1] and ISO 14044.[2] This ensures usability in future LCA studies. According to the above standards, the following aspects regarding the methodology are described in detail: system boundaries and allocation procedures (including cut-off rules), data requirements and data quality requirements, assumptions and limitations, and the intended application of the study.
In detail, the following items should be considered in an LCA (ISO 14040):

- The product system to be studied, its function(s), and the functional unit
- System boundaries
- Data requirements and data quality
- Allocation procedures
- Categories, methods, and interpretation at impact assessment
- Type of critical review, if any, and
- Type and format of the report required for the study.

The ISO standards require a clear description of the following aspects of the data (ISO 14040):

- Time related coverage
- Geographical coverage
- Technological coverage
- Precision, completeness and representativeness of the data
- Consistency and reproducibility of the methods used throughout the LCA
- Sources of the data and their representativeness
- Uncertainty of the information.

- **European Commission Integrated Products Policy (IPP)**

A more specific standard for building materials is currently under development in the EU. This standard aims to provide a common basis for the development of Environmental Product Declarations (EPDs). EPDs enable all producers to credibly communicate about the environmental performance of

[1] ISO 14040:2006 Environmental management -- Life cycle assessment -- Principles and framework - http://www.iso.org/iso/catalogue_detail?csnumber=37456

[2] ISO 14044: 2006 Environmental management -- Life cycle assessment -- Requirements and guidelines - http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=38498

their products. The Scheme has been developed as part of the EU Integrated Products Policy.[3] One of the overarching goals of IPP is to stimulate demand for greener products through easily accessible, understandable and credible information. A possible tool to achieve this is the use of environmental labeling, of which EPDs are an integral part.

In June 2003, the European Commission adopted its Communication on Integrated Product Policy (IPP), opting for a more voluntary approach to greener products. IPP seeks to minimise environmental degradation caused by products throughout their whole life-cycle. The strategy is based on five key principles:

- Life-cycle thinking: the environmental impact of a product must be considered throughout its whole lifecycle from production to end-of-life ('from the cradle to the grave')
- Working with the market: incentives should be set so that the market moves to encourage the supply and demand of greener products
- Stakeholder involvement
- Continuous improvement
- A variety of policy instruments

To implement its IPP strategy, the Commission will focus on two axes:

- Establishing 'framework conditions': the promotion of policy measures and instruments (such as voluntary agreements, green procurement, taxes and subsidies, life-cycle analysis databases, EMAS, ecolabel) to be used on many different products;
- 'A product specific approach': identification of the most environmentally damaging products and development of pilot projects for these products, after consultation with industry and other stakeholders.

ISO standards 14024, 14021 and 14025: Environment Product Labelling and Declaration

Green labels are not always easy to define, and there is no simple way of categorising all green labels according to what they cover. The International Organization for Standardization (ISO) has developed a classification system for environmental product claims and labels, based on the nature of the claim:

ISO 14024 is for Type I claims. These are declarations which meet criteria set by third parties (not by the manufacturer or retailer themselves), and are based on life cycle impacts. These are award-type labels. As they require the product to meet independently set criteria. The strictness of the criteria depends on the body which controls the criteria.

ISO 14021 is for Type II claims. These are claims that manufacturers' or retailers' make themselves, often referred to as “green claims”. They can be useful, but much depends on the type of claim that the manufacturer or retailer makes.

ISO 14025 is for Type III claims. These consist of quantified information about products based on life cycle impacts (or Environmental Product Declarations – EPDs). Type III claims should enable products to be compared easily, for example for public procurement purposes, because they consist of quantified information about aspects such as energy output.

DRAFT CEN standard: Sustainability of construction works — Environmental product declarations — Product category rules

The European Committee for Standardization (CEN) contributes to the objectives of the European Union and European Economic Area with voluntary technical standards which promote free trade, the safety of workers and consumers, interoperability of networks, environmental protection, exploitation of research and development programmes, and public procurement.

[3] http://www.euractiv.com/en/sustainability/integrated-product-policy-ipp/article-117512

CEN is a multi-sectoral organization and serves different sectors in different ways. A sector of particular interest in this project is construction. CEN develops European Standards for use in building and civil engineering. These standards cover a wide range of products, materials and structures. Approximately 600 standards that are mandated under the European Union directive for construction products are currently being developed and will lead to CEN marking of the respective products.

The CEN publication – "*Sustainability of construction works — Environmental product declarations — Product category rules*" (CEN TC 350) is used as a guide in this current work. This voluntary European standard (the "draft standard") provides product category rules (PCRs) for Type III environmental declarations for all European construction products and services. It also provides a structure to ensure that all Environmental Product Declarations (EPD) of construction products, services and construction processes are derived, controlled and presented in a harmonised way.

The objective of an EPD is to provide an environmental quantification for a product. The purpose of an EPD in the construction sector is to provide the basis for assessing buildings and identifying those which cause less stress to the environment. This is accomplished through the communication of verifiable, accurate, comprehensive, environmental information for the products and their applications, thereby supporting scientifically based fair choices and stimulating the potential for market-driven continuous environmental improvement.

The objective of the Product Category Rules (PCR) are to ensure:

- The provision of verifiable, consistent and comparable data for EPD, based on LCA (covering the whole life cycle), describing the environmental performance of construction products on a fair and scientific basis;
- The provision of verifiable, consistent and comparable product related technical data or scenarios for the assessment of the environmental performance of buildings;
- The provision of verifiable, consistent and comparable product related technical data or scenarios for the assessment of the health and comfort performance of buildings;
- Informed comparisons between construction products in the context of their application in a building for purchasers and users of construction products;
- The communication of the environmental performance of construction products in particular from business to business, e.g. along the supply chain;
- The communication of the environmental performance of construction products to consumers, if relevant, e.g. in a "DIY" store.
- Declarations based on these PCR are not comparative assertions.

The standardisation process has taken place in an open consultation, as required in ISO 14025. All common issues are covered horizontally (all product types) as far as possible, which minimises vertical (sector specific) deviations.

Where this draft is more specific than the generic ISO standards for LCA (ISO 14040 and 14044) this has been applied in this study.

UK Publicly Available Specification (PAS 2050): Carbon footprinting

Another standard that has been published in the UK is the PAS 2050:2008 (BSI, 2008). The UK's BSI Standards Solutions has developed this specification to provide a consistent approach for measuring the embodied greenhouse gas (GHG) emissions from goods and services at the request of DEFRA (Department for Environment, Food and Rural Affairs) and the Carbon Trust.

The PAS method for measuring embodied GHG emissions of goods and services will enable organisations, e.g. businesses, to effectively measure the climate change related impacts of their goods and services with a view to using this information to improve the climate change related performance of these. The PAS specifies requirements for the assessment of the greenhouse gas (GHG) emissions associated with the life cycle of goods and services. It is applicable to organizations assessing the life cycle GHG emissions of goods and services across their life cycle.

The measurement method:

- Applies to all goods and services with consideration given to how and whether it may need customising for specific product groups, e.g. food, buildings, electronics, etc.
- Considers all lifecycle stages along the supply/value chain of a product (goods and/or services), i.e. from raw materials to end of life
- Includes the six GHGs identified under the Kyoto protocol
- Could be used by all sizes and types of organisations

The PAS is intended as the first step towards a future internationally agreed method for organisations to measure the GHG emissions embodied in their goods and services. It refers only to 'carbon footprinting', however, and does not refer to any other environmental impact categories or resource or energy use. The PAS 2050 is largely based on the ISO standards for LCA.

3 Methodology

3.1 The product system to be studied, its function(s), and the functional unit

The functional unit defines the quantification of the identified functions or performance characteristics of the product. The primary purpose of the functional unit is to provide a reference by which, for a building product or service, the material flows (material input and output data) of an LCA, and the additional information, are normalised.

Reference to the functional unit is one of the requirements for the comparability of LCA data. The functional unit, used as the denominator provides the basis for the addition of material flows and environmental impacts for each of the life cycle stages of the building product or service.

The functional unit of a building product is based on the quantified, relevant functional use or performance characteristics of the construction product when integrated into a building, taking into account the functional equivalent of the building.

In this project 1 kg of material was chosen so that it can be adapted to the LCA study for which the datasets will be used. Although having this as the functional unit for all building materials is not the most practical, due to the way materials are specified, it is necessary for consistency purposes

3.2 System boundaries

The ISO 14040 and the DRAFT CEN standard require all stages of the life cycle to be included in an LCA and in an Environmental Product Declaration respectively. However, this study provides Life Cycle Inventory datasets to be used in full LCA studies. Appropriate life cycle stages for use and end of life have to be added for LCA studies in which the datasets provided in this report are used.

The system boundaries specify which processes are parts of the product system in this project. An EPD can cover all stages of a product's life cycle or a selection of stages, which at minimum shall include the product stage (from cradle to gate). Within the selected life cycle stages all relevant processes shall be included. Processes are considered relevant when the criteria for the inclusion of inputs and outputs apply. The processes which should typically be considered for the product stage are described below. If any of the optional life cycle stages are calculated based on scenarios, the same system boundaries apply.

The product stage is a mandatory life cycle stage. It includes:

- Extraction of raw materials and biomass production;
- Manufacturing of the product;
- Generation of the energy input, including the production of the energy itself;
- Production of ancillary materials or pre-products;
- Packaging;
- Transportation up to the production gate and internal transport;

- Recycling of materials, including their collection and transport from the system border of the previous system to the production site;
- Waste management processes during the product stage until final waste deposition.

3.3 Allocation procedures

The allocation procedures applied in the development of the datasets presented in this report are in line with the requirements of the "draft standard" which states the following:

"Most industrial processes produce more than one product and as a rule the material flows between them are not linear. Normally more than one input is needed to produce one product. Intermediates and discarded products can be recycled to become inputs for other processes. When dealing with systems involving multiple products and recycling processes, allocation should be considered carefully and justified, however, allocation should be avoided as far as possible.

Allocation shall follow the guidance of ISO 14044:2006-07, clause 4.3.4. Procedures and assumptions shall be transparent and clearly stated and explained in the project report. For construction products the following rules are appropriate:

- *Allocation shall respect the main purpose of the studied processes. If the main purpose of combined processes cannot be defined (e.g. combined mining and extraction of nickel and precious metals), economic allocation may be used to divide resources and emissions between the products.*
- *The principle of modularity shall be maintained. Where processes influence the products environmental performance during its life cycle, they shall be assigned to the module where they occur.*
- *The sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation. This means no double counting of inputs or outputs is permissible.*

Examples:
a) Multi-input: allocation is based on physical causal relationships, i.e. relationship between how the pollutant emission from the process is affected by changes in the input flows.

b) A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials.

c) An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties. Inputs of recycled materials or energy to a product system shall be included without adding their data about environmental impact caused in „earlier" life cycles, but including the data on impacts caused by the collection, transport, and recycling process. Hence, outputs of materials subject to open loop recycling shall be regarded as inputs to the "next" life cycle."

Criteria for the inclusion of inputs and outputs (cut-off rules) in the LCA, information modules, and additional information, support an efficient calculation procedure. They were not applied in order to hide data.

In case of insufficient input data, the cut-off rule shall be 1% of energy usage and of the total mass as inputs into the process; assuming the manufacturing process of this particular input does not constitute a production process with relevant impacts on the environment. The total sum of neglected input per process was a maximum of 5% of energy usage and mass.

In this project there is no allocation undertaken in the foreground systems. Allocation in the upstream processes was undertaken in accordance with the ISO standard 14044. For example, aggregates are allocated on a mass basis; energy carriers (such as coal or natural gas) are generally allocated for energy.

3.4 Categories, methods, and interpretation at impact assessment

Global warming is currently regarded as the most important environmental issue and therefore global warming potential is frequently reported as an output from LCA studies. However, other environmental issues are also pressing. In the recent report "*Global Environment Outlook: environment for development (GEO-4)" (UNEP 2007)* the loss of biodiversity, the impacts of pollution, and the availability of fresh water are identified as key problems next to climate change[4]. Acidification, eutrophication, and photochemical ozone production[5] contribute significantly to those environmental problems. Providing results for other environmental impacts therefore provides the opportunity to identify improvement potentials for these impacts and leaves the decision to prioritise specific environmental issues to the reader.

In line with the "DRAFT CEN standard" the impact assessment in this current project is carried out for the impact categories listed below. The characterisation factors are based on the references listed within that standard, except for the factors for the global warming potential which are based on the most recently published factor by IPCC (2007):

- global warming potential (IPCC 2007)
- acidification potential for air and water (CML, 2001)
- eutrophication potential (CML, 2001)
- photochemical ozone creation potential (CML, 2001)

The "standard" also requires information on the ozone depletion potential. In this study the ozone depletion potential of the materials identified has not been considered. Following the banning of ozone depleting chemicals in the 1987 Montreal Protocol, the atmospheric concentrations of the most important chlorofluorocarbons and related chlorinated hydrocarbons have either leveled off or decreased but the impacts of past emissions on the ozone layer will still be seen for decades to come. Some identified chemicals, while still in use in products, will not be used in new products (at least to an extent that is likely to be of concern).[6]

More recently, no new ozone layer depleting materials have been permitted for use in industrialised countries. The decision about which construction materials to use in a house in New Zealand should not be influenced by their ozone layer depletion, as it is an issue that is essentially "solved". Despite this, there are - undocumented - indications that the data quality on ozone layer depleting emissions may not be consistent.

In addition to the impact categories listed above, datasets on primary energy for non-renewable and renewable are also provided.

3.5 Time related coverage

The New Zealand datasets included inputs of data from manufacturers, economic input-output (I-O) tables, energy inputs and their relevant energy intensities and emissions, transport coefficients, and other sources. The I-O tables, for example, were last published in 2001, from data going back to 1996 (Statistics New Zealand, 2001). While some manufacturing data has remained stable, other aspects have been updated using data from the current year. Similarly, energy data has changed in some

[4] The UNEP report states that up to a third of the world's people are affected by pollution, soil erosion, nutrient depletion, water scarcity, salinity, and disruption of biological cycles which lead to unsustainable land use; "a threat as serious as climate change and biodiversity loss".

[5] Photochemical Ozone Creation Potential (PCOP) is an indicator of the ability of a Volatile Organic Compounds (VOC) to contribute to photochemical ozone formation.

[6] http://en.wikipedia.org/wiki/Montreal_Protocol

respects, but not all. The New Zealand data used is thus from the period 1995 to 2008. The wide time span is typical for such a study, stemming from the unavoidable age and availability of data from different sources. The underlying European data is predominantly from 2000 or later, but data from 1996 is also used, and occasionally earlier.

3.6 Geographical coverage

A combination of European and New Zealand specific data is used. The New Zealand datasets used include overseas data where this is appropriate. Structural steel, for example, is typically imported into New Zealand from Asia or Australia. Because of New Zealand's geographical position and size, construction materials are sourced from a wider geographical range than would be the case for, say, a European country.

3.7 Technological coverage

The New Zealand data was derived from process analyses of either all industry participants, or representative selected manufacturers. Because of New Zealand's somewhat small and isolated economy, its manufacturing technology tends to lag behind larger economies or economic blocks, such as North America or Europe. Less efficient technologies, such as wet-process cement manufacture, are more likely to persist in New Zealand, leading to higher energy and GHG intensities for finished materials or products.

Where a significant portion of an industry had upgraded its technology or capital equipment, preference was given to obtaining data from the manufacturers with newer technology, as being representative of that industry, on the basis that the remaining portion of the industry was likely to follow to the new technology. Where a significant portion of an industry retained older technology, its effect on that total industry was taken into account.

Energy inputs to the New Zealand data were from detailed analysis of local energy industries. Electricity inputs included factors for the varying conditions of hydro inflows and provision of fossil fuels, as well as line and other fugitive losses.

Contributions to the New Zealand data attributable to transport were derived from locally published analyses.

3.8 Consistency and reproducibility of the methods used throughout the LCA

The methodologies applied in this report are consistent with current international standards. All changes to the existing datasets are documented in this report. However, due to the confidential nature of some of the underlying datasets the reproducibility is somewhat restricted. In the details of the hotspot analysis – as shown in Appendix A1 - a high degree of transparency is given.

3.9 Type of review

A critical review of life cycle assessments is a process which aims at ensuring credibility. The ISO 14044 standard requires critical reviews to be performed on all life cycle assessments supporting a comparative assertion disclosed to the public.

Since the data provided in this study might be used for comparative study a critical review has been carried out.

A critical review may be a simple peer review of the final report, or it may be a more integrated quality assurance involving typically three review steps: After the scope definition, after the data collection, and after the conclusion is made.

For this project the following aspects of the project were reviewed:

1. Underlying datasets
2. The final report

Underlying datasets

The original New Zealand data used for this study was published in a report by the Centre for Building Performance Research (Alcorn, 2003). The study for that report received peer review from BRANZ, which was also the funding body. The review considered the methodology, scope definition, and final data. Data sources, their suitability, and their representativeness were reviewed.

The GaBi datasets were reviewed internally by experts not related to the development of the specific datasets. Details of the review are as follows "The LCI method applied is in compliance with ISO 14040 and 14044. The documentation includes all relevant information in view of the data quality and scope of the application of the respective LCI result / data set. The dataset represents the state-of-the-art in view of the referenced functional unit."

Final Report

The final report was reviewed by Roman Jaques from BRANZ Ltd.

3.10 Type and format of the report required for the study.

The output of this work is two-fold – an Environmental profile and the documentation of the data and approach.

The information will also be provided in an XML format (as defined by the European Reference System for Life Cycle Data) as this will allow the efficient integration of this dataset into the most common LCA software tools used by both national and international researchers and into national public databases.

3.11 Sources of the data and their representativeness

3.11.1 New Zealand specific data

The Centre for Building Performance Research at Victoria University Wellington has calculated New Zealand-specific data on embodied energy and CO_2 emissions for approx. 60 different building materials Alcorn (1995, 1998, 2003, 2008).

This New Zealand data was derived from a process-based hybrid analysis. Inputs were included for all aspects of the foreground process, to the factory gate. The study covered energy consumption and CO_2 emissions from resource extraction, transport, and processing, i.e., "cradle to gate". Included were material inputs, energy inputs, transport, capital equipment, outputs and extra information. Upstream process data was included where it was readily available. No cut-offs were applied to the analyses. Instead, whenever the acquisition of further upstream data would have required a greatly increased effort, the process analysis was truncated and data from tables of national economic input-output (I-O) coefficients were substituted in.

The precision of the capital equipment data varied according to what was available from industry, but was always derived from dollar values and I-O energy/$ coefficients. In some cases detailed information was used for capital equipment values. In others, the average value for the relevant industry was obtained from the input-output tables. In all cases the capital equipment value was small as a percentage of the total inputs, being typically less than 2%.[7] The inclusion of capital equipment and I-O data at truncation points means the New Zealand derived data was from complete analyses, to the factory gate.

[7] Because of the small percentages involved Frischknecht suggests capital equipment does not have to be included in LCA studies of construction materials (Frischknecht et al. 2007).

The whole life cycle was not covered, however, because the use phase, demolition, and end-of-life need to be the topic of subsequent studies, given the variability and lack of specific data for these parameters in New Zealand. The costs of such studies were beyond the funding available for this exercise.

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.

CO_2 emissions were calculated using New Zealand specific CO_2 coefficients for the different fuel types[8].

The study was first published in 1995, and has been updated several times since then. The latest published update is from 2003 and was used for this study, although more recent data contained in a PhD thesis (Alcorn, 2008) was used in some instances.

Because of New Zealand's small size, it is sometimes possible to analyse all the manufacturers in one industry. In other cases, where there were many participants, representative manufacturers were chosen, based on their size within the industry and the prominence of their level of technology. Other data sources included Jaques (2001) "Environmental impacts associated with Concrete manufacture – preliminary study".

3.11.2 International data

GaBi is a software tool for LCA studies, developed at the University of Stuttgart, and the consultancy PE International GmbH. Part of the software is a database for building materials, based on average German industry data collected by PE International between 1996 and 2006, amended and checked for consistency with literature data. The documentation describes the production process, applied boundary conditions, allocation rules etc. for each product. The database is compliant with the ISO Standards 14040 and 14044. The study covers resource extraction, transport, and processing, i.e., "cradle to gate". Included are material inputs, energy inputs, transport, outputs and emissions related to energy use and production. Capital equipment is excluded. Based on the material and energy inputs and emissions, a range of different environmental impacts, e.g. climate change, ozone depletion, acidification etc, as well as renewable and non-renewable energy consumption, can be calculated.

3.11.3 Combined New Zealand and international data

Hotspot analyses are used to identify the key inputs in the European data that require attention to adapt them to New Zealand manufacturing realities. Some aspects of the European data, however, do not easily match the New Zealand data.

Steel production is an example of the difficulty in integrating European data with New Zealand data and manufacturing conditions. The production of steel billets for steel sheet manufacture in New Zealand requires a different and more complicated process than the production of steel billets for steel sheet manufacture in Europe. This is because of the particular characteristics of the iron sand used as a source material, as compared with typical iron ore used in Europe. Complete data, including all inputs and outputs, for analysis of a full range of environmental impacts, is only available for the European data, and not for the New Zealand data. Consequently, the European data is used, although this entails a significant underrepresentation of the energy and other inputs to the process, and the GHGs emitted.

Energy data for New Zealand is not as up-to-date in the GaBi database as New Zealand analyses. Additionally, some data, such as for natural gas, is not available from New Zealand sources, in the necessary detail to allow comprehensive environmental impact analysis and therefore not available in the GaBi database or other LCA databases. Accordingly, natural gas data for other countries,

[8] The CO_2 emissions related to the electricity mix dependent on the type of primary energy used to generate the electricity. In New Zealand for example a large contribution is from hydro and the resulting CO_2 emissions related to the electricity mix are therefore low compared to an electricity mix that is for example based on mainly fossil fuels.

specifically Australia, was used. This, however, introduces significant errors in at least some key impact categories, such as CO_2 emissions associated with natural gas use.

The GaBi data from European sources is not, then, always appropriately representative of New Zealand manufactured building materials. Details of the particular difficulties and approaches to overcome these differences are given in the description of the results for each material.

The significant variation between New Zealand and European manufacturing, and the resulting data differences, has highlighted a difficulty with using data from one country or region in another country that does not share common manufacturing resources. This inherent problem would ideally be overcome with a comprehensive collection and analysis of New Zealand specific data, including data for other sectors such as energy and transport.

4 Building Materials

A literature review on relevant New Zealand reports was undertaken to identify the key materials for residential and commercial buildings in New Zealand, with a focus on materials produced in New Zealand. The results were summarised to produce a list of the key building materials to be analysed.

4.1 Selection of building materials to generate LCA datasets for

As part of the process to identify the product systems or key materials used in New Zealand's built environment, including residential and commercial, and therefore for use in this study, a number of houses were modelled, of different sizes and construction types (Alcorn, 2008, Szalay, 2006).

Using, initially, a 1970's house design that is approximately representative of the average New Zealand housing stock (Johnstone, 2001), a selection was established that represents the most commonly used materials for the construction of a house. Whether the house was modelled with a concrete floor, timber floor, weatherboard or masonry exterior, or with a steel or concrete tile roof, the list of materials remained the same, although the relative importance of the materials changed to some extent.

The Exemplar House (Wilson 2002) was also modelled. The Exemplar House was specifically designed to be used as an example of residential costing. It could be said to more closely reflect current construction practice in New Zealand. The most important materials from this analysis were also included in the selection of materials.

The input output tables from the New Zealand economy (Statistics New Zealand, 2001) were also examined to identify key building materials. No building materials appeared from this examination that were not already on the list.

Finally, the BRANZ Building Materials Survey (Page, 2005) was also examined to help prioritise the most important materials used in the New Zealand construction industry.

A list of the most important materials, in approximate order of importance, but also organised into material types, is as follows:

- Timber, gauged
- Timber, mouldings
- Particle board
- Plywood

- Concrete, 17.5, 30, 40 MPa
- Pre-cast concrete
- Concrete tiles
- Fibre cement sheet

- Steel
    - Structural steel
    - Sheet steel (roofing etc)
    - Steel wire Products
    - Reinforcing steel
    - Steel Tiles

- Aluminium, extruded, factory painted
- Paint, water based
- Gypsum plasterboard
- Fired clay brick
- Glass, float (aluminium framed window)
- Glass fibre insulation
- Polyethylene (PE) membrane (building wrap)

A subsequent list of the next most important materials was also identified:

- Extruded Polystyrene (PS)
- PE mouldings
- Polyvinyl Chloride (PVC) extrusions
- Polyethylene terephthalate (PET)
- Paint, solvent based
- Stainless steel
- Copper
- Glulam

4.2 List of building materials to be covered

The basis for the use of overseas data to adopt and/or adapt to New Zealand conditions is the extended GaBi database (LBP, PE 2007). The materials that are selected as the most relevant and feasible construction materials to be covered are given in Table I. Some materials, such as concrete, required the adaptation of further, upstream, materials, such as cement for concrete and fibre cement sheet production. Other upstream non-material analysis was also necessary for contributing inputs, such as for the New Zealand electricity grid. The final list of finished building materials analysed is thus

Table I Building materials covered

NZ Building Material	Origin of new dataset and comments	Original GaBi dataset to be used
Concrete, 17.5 MPa	*adapted*	*DE: Ready Mix Concrete C 20/25*
Concrete, 40 MPa	*adapted*	*DE: Ready Mix Concrete C 30/37*
Pre-cast concrete	*Dataset generated*	*n/a*
Concrete tiles	*adapted*	*DE: Concrete Roof Tile*
Reinforcing steel	*adapted*	*DE: Reinforced steel (wire)*
Structural Steel	*adapted*	*DE: Steel billet as key input*
Sheet steel (roofing)	*adapted*	*DE: Steel Sheet, galvanized*
Paint, water based	*adapted*	*DE: Emulsion paint, resin-based*
Fired clay brick	*adapted*	*DE: Bricks (average)*
Glass fibre insulation	*adapted*	*DE: Glass Wool (elastic felts)*
Polyethylene Foil	*adapted*	*DE: Polyethylene foil (PE-LD) (no additives)*
Fibre cement sheet	*Dataset generated*[9]	*n/a*
Aluminium, extruded, factory painted	*adapted*	*DE: Aluminium extrusion profile*
Glass Window (Aluminium Frame)	*adapted*	*n/a*
Gypsum Plasterboard	*Dataset from previous NZ work*	*n/a*
Timber, sawn wood	*Dataset from previous NZ work*	*n/a*
Particle board	*Dataset from previous NZ work*	*DE: Particle board (Standard FPY; 8,5% moisture)*
Plywood	*Dataset from previous NZ work*	*DE: Plywood board (5 % humidity)*

[9] Fibre cement facade sheets are produced very differently in Germany than in New Zealand. As a New Zealand specific recipe is available, this material dataset is newly built up.

5 Methodology for Hotspot Analysis

Using the product models that lie behind the original GaBi datasets for the building materials, the upstream chains for those material datasets were analysed for their contribution to the environmental impacts that are associated with each product.

For each building product, all specified environmental impact categories were analysed to identify the major contributors to the respective impact category. For each product, the individual unit processes (e.g. a process to describe the environmental impacts that are associated with a cement kiln) and upstream datasets (e.g. a dataset that describes the impacts that are associated with the provision of 1 kWh electric energy) that contributed to at least 80 % of the impacts in each category (starting with the dataset that had the greatest share in impacts) were listed.

Tables reproduced in Appendix 1 give the relative contributions from the different processes to the environmental impacts for the impact categories that were considered. Note that each process is listed if it contributes to the first 80 % of the impacts in at least one impact category. Note also that this selection criterion may yield different processes to be listed for quite similar (but not identical) building products.

The tables also indicate the processes that are identified to be adapted to meet New Zealand specific conditions. If processes - sometimes even the most relevant ones - are not indicated to be exchanged, either they do not contain upstream elements that are significantly different between New Zealand and overseas, or there are other reasons - such as the unavailability of appropriate (inter)national specific materials data. In these instances, the overseas data is retained unchanged.

The New Zealand electricity grid mix was derived by PE International from the percentages of energy types in the New Zealand electricity grid, using the New Zealand Energy Data File, and Energy Greenhouse Gas Emissions reports to 2005. A comprehensive analysis of the New Zealand electricity industry including factors for the varying conditions of hydro inflows and provision of fossil fuels appears not to be included. The energy consumption by the power plants of 2.54% and the transmission losses of 9,38% have been taken into account based on International Energy Statistics. A comparison of the NZ electricity grid contributing primary energy percentages shows that the percentages indicated by the GaBi documentation for this process, and the percentages derived by Alcorn (2008) from the New Zealand Energy Data File (MED, 2008a) and New Zealand Energy Greenhouse Gas Emissions (MED, 2008b), are slightly different. The GWP of the energy mix generated by PE International (GaBi) is 0.27 kg CO_2 equiv./kWh and the value based on MED data is 0.24 kg CO_2 equiv./kWh. The GaBi value is with 0.27 kg CO_2 equiv./kWh in a similar range and can be considered as a more conservative figure. The GaBi dataset also allows the calculation of other environmental impacts such as Eutrophication, Acidification and Photochemical oxidant formation which are also presented in this report.

The same method of simulating the New Zealand electricity grid mix was used for all materials during adaptations from GaBi to New Zealand models where electricity was considered.

It should be noted that Australian natural gas has a CO_2 equiv. emission factor that is some 25% higher than the New Zealand equivalent. (MED, 2007; LBP, PE, 2007) This however is just one of many emissions factors that result from a dataset such as thermal energy from natural gas. As this is an individual figure, whereas the Australian figure is part of a comprehensive dataset, the Australian figure has been used. This way all emissions factors (i.e. Eutrophication, Acidification, POCP) resulting from thermal energy production from natural gas are consistent.

6 Results

6.1 17.5 MPa Ready Mix Concrete

6.1.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact from the production of Ready Mix Concrete C 20/25 are noted for the key impact categories as follows.

For Primary Energy (non-renewable) the key contributors are pulverised lignite, hard coal mix, diesel from the refinery, and fly ash from the hard coal plant. Their contribution to Primary Energy (non-renewable) ranges from 10 – 20% of the total. The hot spots are the hard coal mix and the diesel from the refinery at around 18% each.

For Primary Energy (renewable) the biggest hot spot contributors are the power grid mix at almost 50% (from the cement clinker mix production {kiln process}) and the power grid mix (from the Portland cement process) at 17%.

For the Global Warming Potential (GWP 100 years) the hot spot is the cement clinker mix production (kiln process) at over 70%.

For the Eutrophication Potential the hot spots are the cement clinker mix production (kiln process) at almost 60% and Transport at almost 20%.

For the Photochemical Ozone Creation Potential (POCP) the hot spots are the cement clinker mix production (kiln process) at 55% and Transport at just over 10%.

6.1.2 New Zealand Specific Environmental Profile

Material (kg)	Energy renewable	Energy non Renewable	GWP	AP	EP	POCP
	[MJ]	[MJ]	[kg CO_2 Equiv.]	[kg SO_2 Equiv.]	[kg PO_4^{3-} Equiv.]	[kg C_2H_2 Equiv.]
Concrete, 17.5 MPa	0.055	0.606	0.102	0.00021	0.000035	0.000019

Density: 2365 kg/m^3

6.1.3 Profile Derivation

The model for cement was adapted from the GaBi datasets. The New Zealand electricity grid mix was inserted to replace the GaBi German electricity mix.

The GaBi model for rotary cement kilns, clinker production, and grinding was used, but adjusted to New Zealand conditions for energy inputs and emissions, following Jaques (2001).

For concrete production, the New Zealand electricity mix was substituted into the German model. In addition, ratios for aggregate, fly ash, sand and water were adjusted from the German model, as these are noticeably different from New Zealand practice. Typical transport distances for inputs and for delivery were adapted from New Zealand conditions (Jaques, 2001).

It should be noted that all datasets have a lower energy consumption than data provided by Alcorn (2003). This is most likely related to difference in cement manufacturing.

6.2 40 MPa Concrete

6.2.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact of the production of Ready Mix Concrete C 30/37 are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are pulverised lignite, hard coal mix, the power grid mix [from the cement clinker mix production (kiln process)] and diesel from the refinery. Their contribution to Primary Energy (non-renewable) ranges from 10 – 22% of the total. The hot spot is the hard coal mix at 22 % contribution.

For the Primary Energy (renewables) the biggest contributors or hot spots are the power grid mix at 50 % [from the cement clinker mix production (kiln process)] and the power grid mix for the Portland cement process at 18 % contribution.

For the Global Warming Potential (GWP 100 years) the hot spot is the cement clinker mix production (kiln process) at over 80 %.

For the Acidification Potential (AP) the hot spots are the cement clinker mix production (kiln process) at almost 65 % and Transport at just over 10 % contribution.

For the Eutrophication Potential (EP) the hot spots are the cement clinker mix production (kiln process) at almost 70 % and Transport at just over 12 % contribution.

Finally, for the Photochemical Ozone Creation Potential (POCP), the hot spots are the cement clinker mix production (kiln process) at 62 % and Transport at almost 10 % contribution.

6.2.2 New Zealand specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Concrete, 40 MPa	0.083	0.920	0.158	0.00031	0.000051	0.000028

Density: 2365 kg/m^3

6.2.3 Profile Derivation

The method for adapting GaBi data followed the same pattern as for 17.5 MPa concrete.

6.3 *Pre-cast concrete*

A hot spot analysis was not carried out for pre-cast concrete as this dataset was specifically developed for this project.

6.3.1 New Zealand Specific Environmental Profile

Material (kg)	**Energy renewable [MJ]**	**Energy non Renewable [MJ]**	**GWP [kg CO_2 Equiv.]**	**AP [kg SO_2 Equiv.]**	**EP [kg PO_4^{3-} Equiv.]**	**POCP [kg C_2H_2 Equiv.]**
Pre-Cast Concrete	0.151	1.057	0.170	0.00034	0.000053	0.000032

Density: 2455 kg/m^3

6.3.2 Profile Derivation

The dataset for pre-cast concrete was specifically developed for this project. German data was adapted to more closely reflect the New Zealand manufacturing realities for cement and electricity. Aggregate, sand, and fly-ash data was adopted from the GaBi datasets.

Data for diesel, and lubricants, used at the manufacturing plant, and for transport, was adopted unchanged from the German data. German transport data was used, although the transport distances were adapted to New Zealand conditions.

Cement was calculated as detailed for 17.5 MPa Ready Mix Concrete. As with 17.5 and 40 MPa concrete, data for aggregate and sand was adapted from the German GaBi data. Electricity data used was from the GaBi New Zealand electricity grid mix, using 2002 data. Fly ash was from GaBi data. The quantities of these inputs were adapted to reflect New Zealand manufacturing practice.

Data for the quantity of reinforcing steel was adopted from the GaBi data, using the New Zealand adapted reinforcing steel model. It should be noted that pre-cast concrete typically uses drawn steel cable for reinforcing, whereas the reinforcing model used was for solid reinforcing bar. While drawn steel cable is potentially from the same steel source as solid steel reinforcing bar, extra manufacturing, and associated impacts, can be expected for drawn steel cable.

Data for the natural gas used for curing pre-cast units was for Australian natural gas, rather than New Zealand gas. The Australian natural gas model was used as a proxy for New Zealand natural gas, since no comprehensive data was available on the multiple impact parameters of New Zealand natural gas. It should be noted that Australian natural gas has a CO_2 emission factor that is some 25% higher than the New Zealand equivalent. This is not significant, as thermal energy from natural gas makes up only 0.006% of the potential global warming impacts of the curing process of pre-cast concrete.

6.4 *Concrete Roof Tile*

6.4.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact of the production of the concrete roof tiles are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are silica sand (Excavating and processing), the power grid mix (from the Electricity plan), colour (added to the concrete mix), and Portland cement. Their contribution to Primary Energy (non-renewable) ranges from 13 – 36% of the total. The hotspot is the Portland cement at 36 % contribution.

For Primary Energy (renewable) the biggest contributors are silica sand (Excavating and processing), the power grid mix (from the Electricity plan] and colour (added to the concrete mix). Their contribution to Primary Energy (renewable) ranges from 13 – 66% of the total). The hotspot is the Power grid mix at 65 % contribution.

For Global Warming Potential (GWP 100 years) the hotspots are silica sand (Excavating and processing) at 12 % and Portland cement at 66 % contribution.

For Acidification Potential (AP) the biggest contributors are silica sand (Excavating and processing), colour (added to the concrete mix) and Portland cement. Their contribution to AP ranges from 11 – 59 % of the total. The hot spot is the Portland Cement at 59 % contribution.

For the Eutrophication Potential (EP) the biggest contributors are silica sand (Excavating and processing), Transport of the sand (added to the concrete mix) and the Portland cement. Their contribution to EP ranges from 10 – 59 % of the total. The hotspot is the Portland Cement at 59 % contribution.

Finally for the Photochemical Ozone Creation Potential (POCP) the biggest contributors here are silica sand (Excavating and processing) at 12 % with the hot spot being the Portland Cement at 55 % contribution.

6.4.2 New Zealand specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Concrete tiles	0.267	2.402	0.263	0.00061	0.000072	0.000052

6.4.3 Profile Derivation

The same cement model used for 17.5 and 40 MPa Ready mix concrete was used for concrete tiles. It should be noted that in New Zealand concrete tile manufacture, a different aggregate is used, consisting of coarse sand, without large aggregate. Energy use for aggregate is however very similar for all types of aggregates, therefore the difference in aggregate type used in this model is not significant.

The New Zealand electricity grid mix was inserted to replace the GaBi German electricity mix.

The natural gas profile in the GaBi model was replaced with the Australian natural gas model as a proxy for New Zealand natural gas, since no comprehensive data was available on the multiple impact parameters of New Zealand natural gas. It should be noted that Australian natural gas has a CO_2 emission factor that is some 25% higher than the New Zealand equivalent. This is not significant, as thermal energy from natural gas makes up only 0.58% of the potential global warming impacts of a concrete roof tile.

6.5 *Reinforcing Steel (wire)*

6.5.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact of the production of reinforced Steel (wire) are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are the power grid mix (for the Crude Steel (electric furnace)) the power grid mix (for Reinforced steel (wire) with the former being the hot spot at 47 % contribution).

For Primary Energy (renewable) the biggest contributors are energy from biomass (for the Ferro silicon NO (90%), the power grid mix (for the Ferro silicon NO (90%), energy from biomass (for the Ferro silicon ZA (90%), the power grid mix (for the Crude Steel (electric furnace)), and the power grid mix (for the Reinforced steel (wire). Their contribution to Primary Energy (renewable) ranges from 11 – 32% of the total, with the hot spot being the power grid mix for the Crude Steel (electric furnace)) at 32 % contribution.

For the Global Warming Potential (GWP 100 years) the biggest contributors are the Steel plant (electric furnace), the power grid mix (for the Crude Steel (electric furnace)), the power grid mix (for the Reinforced steel (wire) and the thermal energy from natural gas. The hot spot is the power grid mix (for the Crude Steel (electric furnace)) at 42 % contribution.

For the Acidification Potential (AP) the biggest contributors are the Ferro manganese (90 %; Low Carbon), the power grid mix (for the Crude Steel (electric furnace)) and the power grid mix (for the Reinforced steel (wire). Their contribution to AP ranges from 11 – 45 % of the total. The hotspot is the power grid mix (for the Crude Steel (electric furnace)) at 45 % contribution.

For the Eutrophication Potential (EP) the biggest contributors are the power grid mix (for the Crude Steel (electric furnace)) and the power grid mix (for the Reinforced steel (wire). The hotspot is the former of the two power grid mixes at 45 % contribution.

Finally, for the Photochemical Ozone Creation Potential (POCP) the biggest contributors are the Steel Plant (electric Furnace) and the power grid mix (for the Crude Steel (electric furnace)). The Steel Plant (electric Furnace) is the hot spot at 56 % contribution.

6.5.2 New Zealand specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Reinforcing steel	2.918	5.494	0.449	0.00125	0.000064	0.000165

6.5.3 Profile Derivation

The basis of the model used is from secondary steel billets, as this reflects the New Zealand situation, where reinforcing steel is made from recycled steel. The natural gas profile in the GaBi model was replaced with the Australian natural gas model as a proxy for New Zealand natural gas, since no comprehensive data was available on the multiple impact parameters of New Zealand natural gas. It should be noted that Australian natural gas has a CO_2 emission factor that is some 25% higher than the New Zealand equivalent. This is not significant, as thermal energy from natural gas makes up only 0.25% of the potential global warming impacts of reinforcing steel.

6.6 Structural Steel

A hot spot analysis was not performed for structural steel since this imported to New Zealand. An overseas dataset has therefore been adopted to Australian conditions by changing the thermal energy and the electricity mix.

6.6.1 Profile Derivation

A large proportion of New Zealand's structural steel comes from Australia. Other major supply regions include Asia.

The German data for structural steel was adapted by applying Australian natural gas and electricity grid mix data to the steel profile production stage.

Data for the production of steel billets (the bulk output from the primary steel mill) remained German data, including energy inputs. In practice, primary steel production and secondary product production, such as beams and other structural steel profile sections, are produced on the same site. Nevertheless, Australian primary steel production and European primary steel production are likely to use very similar technologies with similar impacts.

No transport component was included for shipping structural steel to New Zealand as this can come either from Australia or Asia.

6.6.2 Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Structural Steel	0.877	24.163	1.802	0.00534	0.000471	0.000805

6.7 *Sheet steel (roofing)*

Note: in New Zealand steel sheets are made from primary steel, whereas GaBi datasets calculate them as made from recycled steel. This has been taken into account for the New Zealand dataset.

6.7.1 Environmental Hot Spots in GaBi dataset

The environmental ‘hot spots' that are critical to the total environmental impact of the production of galvanised steel sheeting are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are the power grid mix (for the Crude Steel (electric furnace)), Hard Coal and power grid mix for Steel sheeting (75mm). Their contribution to Primary Energy (non-renewable) ranges from 11 – 34% of the total. The hot spot is the first of the power grid mixes listed at 34%.

For Primary Energy (renewables) the biggest contributors are the Zinc redistilled (Nordenham), energy from biomass (for the Ferro silicon NO (90%), power grid mix (for the Ferro silicon NO (90%), energy from biomass (for the Ferro silicon ZA (90%), power grid mix (for the Crude Steel (electric furnace)), and the power grid mix (for the Steel sheeting (75 mm). Their contribution to Primary Energy (renewable) ranges from 10 – 28% of the total). The hot spot is the power grid mix (for the Crude Steel (electric furnace)) at 28%.

For the Global Warming Potential (GWP 100 years) the biggest contributors are the power grid mix (for the Crude Steel (electric furnace)), the power grid mix (for the Steel sheeting(75 mm)) and the production of Hot-rolled steel. Their contribution to GWP ranges from 13 – 29 % of the total). The hot spot is the power grid mix (for the Crude Steel (electric furnace)) at 29%.

For the Acidification Potential (AP) the biggest contributors Zinc redistilled (Nordenham), the power grid mix (for the Crude Steel (electric furnace)), the power grid mix (for the Steel sheeting(75 mm)) and the production of Hot-rolled steel. Their contribution to AP ranges from 11 – 28 % of the total. The hotspot is the power grid mix (for the Crude Steel (electric furnace)) at 28%.

For the Eutrophication Potential (EP) the biggest contributors are the power grid mix (for the Crude Steel (electric furnace)), the power grid mix (for the Steel sheeting(75 mm)) and the production of Hot-rolled steel. Their contribution to EP ranges from 12 – 26 % of the total. The hot spot is the power grid mix (for the Crude Steel (electric furnace)) at 26%.

Finally, for the Photochemical Ozone Creation Potential (POCP) the biggest contributors are the Steel Plant (electric Furnace) and the power grid mix (for the Crude Steel (electric furnace)). The Steel Plant (electric Furnace) is the hot spot at 46% contribution.

6.7.2 New Zealand specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Steel Sheet	1.963	30.651	2.284	0.00652	0.000580	0.000955

6.7.3 Profile Derivation

The GaBi process for steel sheet was adopted. The sheet thickness is 0.75mm, with a 0.02mm coating of zinc. Typical equivalent New Zealand thickness is 0.55mm for the sheet. The underlying GaBi process uses recycled steel as the main input. This value is altered in the model to effectively remove recycled steel as an input to the steel sheet model. The iron input data used in the adapted model is from iron ore of European origin. It should be noted that in New Zealand steel sheet is made in a unique fashion from iron sand, which requires a similarly unique smelting procedure. This is likely to result in a higher value than the value calculated by this model.

6.8 *Emulsion paint, resin-based*

6.8.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact of the production of the Emulsion paint (resin based) are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are the Styrene acrylate (50 %), Titanium dioxide pigment (for Manufacturer 1) and Styrene butyl acrylate copolymer (50 % solid). The hot spot is the Titanium dioxide pigment at 31 % contribution.

For Primary Energy (renewable) the biggest contributors are the Titanium dioxide pigments (both manufacturers) with Manufacturer 1 the greater of the two and the hot spot at 38 % contribution.

For the Global Warming Potential (GWP 100 years) the biggest contributors are the Styrene acrylate (50 %), the Titanium dioxide pigment (Manufacturers 1 and 2). The Titanium dioxide pigment (Manufacturer 1) is again the hot spot at 34 % contribution.

For the Acidification Potential (AP) the hot spots are the Titanium dioxide pigment (Manufacturers 1 and 2) at 54 % and 41 % contributions respectively.

For the Eutrophication Potential (EP) the hot spots are again the Titanium dioxide pigment (Manufacturers 1 and 2) at 35 % and 26 % contributions respectively.

Finally, for the Photochemical Ozone Creation Potential (POCP) the biggest contributors are the paint (dispersion) for both Manufacturers with Manufacturer 2 being the hot spot at 78 % contribution.

6.8.2 Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Paint, water based	1.004	43.616	2.077	0.03687	0.000522	0.017068

6.8.3 Profile Derivation

The only change made to the GaBi German model for emulsion paint is to replace the German electricity mix with the New Zealand one. Other energy inputs are left unaltered.

It should be noted that natural gas and electricity are approximately equal as energy inputs to paint manufacture in New Zealand. This is not significant because although New Zealand natural gas has a noticeably lower CO_2 emission factor than the German value that is retained in the model, not much gas is used for paint manufacture.

6.9 *Bricks (average)*

6.9.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact of the production of Bricks are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are the Natural gas mix and the power grid mix of which the Natural Gas mix is the hot spot at 72 % contribution.

For Primary Energy (renewables) the hot spot is Wood shavings at 95%.

For the Global Warming Potential (GWP 100 years) the biggest contributors are the brick production, with 159 % contribution. Wood pulp and shavings as a porosity agent have a negative GWP. The stored Carbon is emitted as CO_2 in the brick production and explains the greater than 100% contribution from brick production.

For the Acidification Potential (AP) the hotspot is the Brick production at 89 % contribution.

For the Eutrophication Potential (EP) the biggest contributors are the Natural gas mix and the Brick production of which the Brick production is the hot spot at 69 % contribution.

Finally, for the Photochemical Ozone Creation Potential (POCP) the hotspot is the Brick production at 77 % contribution.

6.9.2 New Zealand specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Fired clay brick	0.355	2.213	0.246	0.00035	0.000030	0.000022

6.9.3 Profile Derivation

New Zealand brick manufacture employs a combination of newer technologies based on gas firing, and older technologies that use either gas or coal for firing. The German data was used as a basis, although gas fired technology is the typical manufacturing method. The resulting energy and CO2 figures in the model are therefore likely to be somewhat lower than the New Zealand figures really are.

The main changes to the GaBi model were the use of the New Zealand electricity mix in place of the German mix, and the use of Australian natural gas in place of the German data. The quantity of gas used was changed to reflect the average New Zealand figure for gas use (Alcorn, 2003). The quantity of electricity used was also changed to reflect the average New Zealand figure. The quantity of coal used remained as per the German data.

6.10 Glass Wool (elastic felts)

6.10.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact of the production of Glass Wool (elastic felts) are noted for the key impact categories as follows.

For Primary Energy (non renewable) the hotspot is the power grid mix for the Melt at 34 % contribution.

For Primary Energy (renewable) the hot spots are the power grid mix for the Melt at 34 % and the wooden pellets (40% moisture) at 30 % contribution.

For the Global Warming Potential (GWP 100 years) the biggest contributors are Soda and the power grid mix for the Melt at 32 %.

For the Acidification Potential (AP) the biggest contributors are the glass wool fibre, the Borax penta hydrate, Soda, and the power grid mix for the Melt. The hotspot is the power grid mix at 25 % contribution.

For the Eutrophication Potential (EP) the biggest contributors are again the glass wool fibre, the Borax penta hydrate, Soda, and the power grid mix for the Melt. This time, it is the Soda which is the hot spot at 20 % followed closely by the glass wool fibre at 16 % contribution.

Finally, for the Photochemical Ozone Creation Potential (POCP) the hotspot is the glass wool fibre at 60 % contribution.

6.10.2 New Zealand specific Environmental Profile

Material (kg)	**Energy renewable [MJ]**	**Energy non Renewable [MJ]**	**GWP [kg CO_2 Equiv.]**	**AP [kg SO_2 Equiv.]**	**EP [kg PO_4^{3-} Equiv.]**	**POCP [kg C_2H_2 Equiv.]**
Glass fibre insulation	7.791	21.474	1.660	0.00540	0.000575	0.000952

Density: 22 kg/m^3

6.10.3 Profile Derivation

The only changes to the GaBi model were the use of the New Zealand electricity mix in place of the German mix, and the use of Australian natural gas in place of the German data.

It should be noted that no New Zealand data is available for New Zealand manufacture of glass fibre insulation to compare with overseas data. Similarly, no direct comparisons can be made with the New Zealand and overseas manufacturing methods. It is therefore assumed that the methods are sufficiently similar to not warrant attention.

6.11 Polyethylene foil

6.11.1 Environmental Hot Spots in GaBi dataset

The environmental 'hot spots' that are critical to the total environmental impact of the production of Polyethylene foil are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are the Natural gas mix, the Naphtha from the refinery and the power grid mix (Polyethylene low density granulate). The hot spot is the Naphtha from the refinery at 45 % contribution.

For Primary Energy (renewables) the biggest contributors are the power grid mix (Polyethylene low density granulate) and the power grid mix (Polyethylene foil) with the former being the hot spot at 59 % contribution.

For the Global Warming Potential (GWP 100 years) the biggest contributors are the Natural gas mix and the Naphtha from the refinery. The Naphtha is the hot spot with 50 % contribution.

For the Acidification Potential (AP) the biggest contributors are the Naphtha from the refinery and the two power grid mixes. The hot spot is the power grid mix (Polyethylene low density granulate) at 29 % contribution.

For the Eutrophication Potential (EP) the biggest contributors are the Naphtha from the refinery, Thermal energy from fuel oil, and the power grid mix (Polyethylene low density granulate). The hot spot is the Naphtha from the refinery at 23 % contribution.

Finally, for the Photochemical Ozone Creation Potential (POCP) the biggest contributors are the Naphtha from the refinery, the Steam Cracker (Euro pipeline), and the Polyethylene low density granulate. The hotspot is the Polyethylene low density granulate at 38% contribution.

6.11.2 New Zealand specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
PE membrane (building wrap)	3.091	83.427	2.368	0.00731	0.000547	0.001524

6.11.3 Profile Derivation

The GaBi model for PE membrane remains unchanged, other than the electricity grid mix for New Zealand being used in place of the German mix. Plastic granulate for manufacture in New Zealand is typically from European sources suggesting a close correlation between New Zealand and European plastics data.

It should be noted that the calorific value of the feedstock for making the plastic resin is included in the non-renewable energy figure. This is a different methodological approach from Alcorn (2003) who counts only the calorific value of the non-renewable (fossil fuel) energy that is actually combusted during the process, but not the calorific value which remains in the finished plastic product, and which, in New Zealand, is likely to be buried in landfill at the end-of-life.

The natural gas profile in the GaBi model was replaced with the Australian natural gas model as a proxy for New Zealand natural gas, since no comprehensive data was available on the multiple impact parameters of New Zealand natural gas. It should be noted that Australian natural gas has a CO_2 emission factor that is some 25% higher than the New Zealand equivalent. This is not significant, as thermal energy from natural gas makes up only 0.02% of the potential global warming impacts of building wrap.

6.12 Fibre cement sheet

A hot spot analysis was not carried out for fibre cement sheets as this dataset was specifically developed for this project.

6.12.1 New Zealand Specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Fibre Cement Sheet	6.708	8.445	0.697	0.00246	0.000191	0.000137

6.12.2 Profile Derivation

The dataset for pre-cast concrete was specifically developed for this project.

Cement was calculated as detailed for 17.5 MPa Ready Mix Concrete. Sand and wood fibre data was adopted from the GaBi datasets. The New Zealand electricity grid mix was used. The Australian dataset for natural gas was used.

The proportions for cement, sand, wood fibre, electricity, and natural gas were adopted from New Zealand data (Alcorn, 2008).

6.13 Aluminium extrusion profile

6.13.1 Environmental Hot Spots in GaBi dataset

The environmental ‘hot spots' that are critical to the total environmental impact of the production of the Aluminium extrusion are noted for the key impact categories as follows.

For Primary Energy (non renewable) the biggest contributors are the Anode production and the power grid mix (Electrolysis) with the power grid mix the hot spot at 53 % contribution.

For Primary Energy (renewables) the hot spot is the power grid mix (Electrolysis) at 95 % contribution.

For the Global Warming Potential (GWP 100 years) the biggest contributors are the power grid mix (Electrolysis) and Electrolysis with the power grid mix the hot spot at 44 % contribution.

For the Acidification Potential (AP) the biggest contributors are the power grid mix (Electrolysis), Electrolysis and Thermal Energy from heavy fuel oil. The hot spot is the power grid mix at 32 % contribution.

For the Eutrophication Potential (EP) the biggest contributors are the power grid mix (Electrolysis), Bauxite mining, and Thermal Energy from heavy fuel oil. The hot spot was the power grid mix at 44 % contribution.

Finally, for the Photochemical Ozone Creation Potential (POCP) the biggest contributors are the power grid mix (Electrolysis) and Electrolysis with Electrolysis the hot spot at 53 % contribution.

6.13.2 New Zealand specific Environmental Profile

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Aluminium, extruded	77.057	124.000	11.312	0.05388	0.001897	0.005081

6.13.3 Profile Derivation

Bauxite, and subsequent alumina, for New Zealand aluminium smelting originates in Australia. The GaBi German model for bauxite mining is used, but with the application of Australian natural gas.

The GaBi German model for the production of Alumina is used, with the insertion of Australian electricity in place of the German electricity mix. This reflects the current situation in New Zealand, as the alumina used for aluminium production is imported from Australia.

The GaBi German model for electrolysis of alumina into aluminium is used, but with the insertion of the New Zealand electricity mix in place of the German one.

The GaBi German model for extrusion of the aluminium into profiles is used, but with the insertion of the New Zealand electricity mix in place of the German one. Other aspects of the German model remain, such as the use of natural gas, although this has, among other things, a higher CO_2 emission factor.

The painting or powder coating of the aluminium profile is not included.

6.14 Glass Window

A typical glass window was modelled, based on international data. The size of this window is 1.5 m x 1.8 m, and it is a double glazed window with an air gap. The cross section of this window is 4 mm of glass, 12 mm of air, 4 mm of glass. The window has an aluminium frame (frame data based on international data, however the aluminium is based on a New Zealand production process. The model also includes seals, hinges and handle.

6.14.1 Environmental Hot Spots in GaBi dataset

Overall, the main impact on GWP is the production of the extruded aluminium window frame. This makes up 68% of the total GWP impact from the window. The glass itself makes up 15% of the GWP impact.

The remaining impacts of the window are distributed mainly to intermediates and products (upstream) used for the coating of the glass, the intermediates and pre-products (also upstream) used for the double-glazing-connections and for some plastics used as part of the window assembly. This is a group of many different products and processes, each with very little respective impact to GWP, but which together make up the remaining 17% of the impacts.

Other relevant impact categories have a very similar breakdown to the GWP figures.

6.14.2 New Zealand specific Environmental Profile

Material (1 item)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Glass Window (double-glazed, aluminium frame)	1643.298	7786.063	598.878	2.62658	0.158462	0.250040

6.15 GIB ® plasterboard

A specific dataset for GIB ® plasterboard is included in this report. Thanks to the availability of the data, no hot-spot analysis of the German dataset was carried out.

A full LCA had been undertaken for Winstone Wallboards Ltd., New Zealand in 2006. This data has been made available for the report.

The reference year for the data is 2005 and includes the following production processes:

- Mining
- Transport of gypsum from Australia to manufacturer in NZ
- Plaster production
- Wallboard production
- Paper production as well as starch production are included

The dataset is based on an average plasterboard across the product range of the manufacturer and does not contain any recycled content.

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
GIB ® plasterboard	5.140	0.494	0.340	0.00099	0.000120	0.000090

6.16 Timber products

A hot spot analysis of timber products has not been done, as comprehensive New Zealand data was available. A large amount of data has been collected by Scion for wood product manufacture in New Zealand, and this data has been incorporated into the datasets used in the models.

All timber datasets are based on log production specific for New Zealand. The dataset for sawn timber is fully based on data that has been collected in a number of projects at Scion. Existing models from the GaBi database have been modified for particle board and plywood as follows. The electricity mix has been replaced with the NZ grid mix and thermal energy from natural gas has been replaced with the respective Australian dataset. It should be noted that most of the thermal energy in all datasets is generated from residual wood which is reflected in the renewable energy consumption.

Carbon dioxide taken up in the timber has been included in the datasets presented. However, the carbon stored in the timber will be partially released in the case of landfilling and would be fully released in the case of thermal utilisation. The datasets are therefore also provided without the uptake of CO_2. In an LCA study the end of life scenario needs to be defined and emissions of CO_2 and/or CH_4 as well as the potential long term storage need to be taken into account. The stored carbon in wood products was calculated as follows:

Assumed 50% of wood mass is carbon.

=> 1kg wood = 0.5 kg Carbon

Molar mass carbon = 12 g/mol.
Molar mass oxygen = 16 g/mol

=> Molar Mass CO_2 = 44 g/mol

0.5 kg / 12 g/mol = 41.67 moles of carbon in 1 kg wood.

41.67 moles x 44 g/mol = 1833.34 grams.

=> 1 kg wood --> 1.83 kg of CO_2

Solar energy stored in timber is assumed to be 18.88 MJ/kg timber (dry matter) (Loo and Koppejan 2002).

6.16.1 Sawn Timber, planed and kiln dried

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Sawn timber, kiln dried (10%)	8.576	1.900	0.154	0.00174	0.000227	0.000229
CO_2 uptake			-1.684			

Density: 500 kg/m^3 (10% humidity)

6.16.2 Particle board

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Particle Board	4.069	5.003	0.279	0.00092	0.000184	0.000320
CO_2 uptake			- 1.417			

Density: 697 kg/m^3 (8.5% humidity)

6.16.3 Plywood

Material (kg)	Energy renewable [MJ]	Energy non Renewable [MJ]	GWP [kg CO_2 Equiv.]	AP [kg SO_2 Equiv.]	EP [kg PO_4^{3-} Equiv.]	POCP [kg C_2H_2 Equiv.]
Plywood	8.054	6.905	0.210	0.00211	0.000295	0.000245
CO_2 uptake			-1.385			

Density: 490 kg/m^3 (5% humidity)

7 Context of LCA activities in Australasia

Life Cycle Assessment has been applied in a sporadic fashion over the last 10 years but appears to have consolidated recently, being seen as a response to increasingly clearly-expressed international demand for objective environmental information about products and services.

The Ministry of Research Science and Technology has therefore recently funded a “Life Cycle Inventory Research project” (Allan 2008). The report includes a survey of practitioners that offers a useful snapshot of the current capacity and capability of individuals practising quantitative environmental assessment in or for New Zealand. The survey reveals a real need for further development nationally, to ensure the development of the field and the make possible the wider application of Life Cycle Thinking across the entire economy. The report concludes that “There are a range of issues confronting the application of life cycle thinking within New Zealand. The creation and maintenance of detailed, accurate and up to date inventory is central to the application of Life Cycle Management (within Business), Life Cycle Assessment (in practice), Greenhouse Gas (accounting), government (Policy) and Research Science and Technology (development). Inventory information needs to be consistent, transparent and available to ensure the wide uptake and use of the various tools and techniques available.” (Allan 2008)

Methodologies described in this project can feed into those discussions. The process applied in this project have been identified as an appropriate fast-track approach to providing relevant data in a short timeframe that can be used immediately for research, policy making, etc.

The Australian Life Cycle Assessment Society (ALCAS)
The Australian Life Cycle Assessment Society (ALCAS) is a professional organisation for people interested in practice, use, development and interpretation of Life Cycle Assessment (LCA).

The purpose of the society is to promote and foster the responsible development and application of LCA methodology in Australia and internationally with a view to making a positive contribution to Ecological Sustainable Development (ESD) and to represent the Australian LCA community in the international arena. The specific objectives of ALCAS are to:

- To promote and foster the appropriate application of LCA in Australia.
- To promote and foster the responsible development of LCA methodology in Australia with consideration of international initiatives and commensurate with local conditions.
- To foster links with the international LCA community.
- To organise a regular LCA Roundtable to facilitate information exchange and discussion on LCA amongst stakeholder groups.
- To contribute to national policies, positions and approaches on LCA and its applications both nationally and internationally.
- Increase education and awareness of LCA among stakeholders including industry, academia, government, non-government organizations, LCA practitioners, end users and the general public.
- To develop a national competence in LCA to meet the environmental challenges both locally and internationally

ALCAS is a not-for-profit organisation with individual and corporate members from industry, government, academia and service organisation.

Australian National Life Cycle Inventory Database Initiative (AusLCI)
ALCAS is working with the CSIRO (Commonwealth Scientific Industrial Research Organisation) to develop the Australian Life Cycle Inventory Database (AusLCI Database) (AUS LCI 2008).

ALCAS's role in the project is the development of data guidelines, communication with LCA practitioners and promoting industry involvement in the database project.

The AusLCI will provide a national, publicly-accessible database with easy access to authoritative, comprehensive and transparent environmental information on a wide range of Australian products and services over their entire life cycle. The database was launched publicly in November 2006.

It is recognised that there are discussion underway in New Zealand to either join or undertake similar activities in New Zealand.

8 Conclusion

The datasets described in this report provide a basis for LCA and carbon footprinting studies of buildings in New Zealand. It can be seen as an interim measure, in the transition period until New Zealand Inc. is able to generate more accurate information based on comprehensive New Zealand industry-specific LCI data.

The applied methodologies could be transferred to other sectors and provide a way to provide Life Cycle Inventory datasets that are applicable in New Zealand. The magnitude of the disparity between manufacturing practices and the detail contained in available data between New Zealand and international sources, however, indicate a modification of the methodology for future combinations of datasets would be desirable.

Some aspects of the European data do not easily match New Zealand data. This is neither a fault with the New Zealand or overseas data, but stems principally from the different manufacturing practices, and to some extent the different products and materials used for similar building tasks.

For many, even basic, materials, conditions vary between Europe and New Zealand. For example, for every five tonnes of aggregate used for concrete production in Europe, one tonne of overburden and soil is removed, as indicated by the GaBi data. In New Zealand there is no known equivalent data, but due to the high reliance on river sourced aggregate, the amount of soil and overburden removed per tonne of aggregate is likely to be much less. Only careful analysis, however, would confirm the magnitude of this difference.

Energy data for New Zealand is not as up-to-date in the GaBi database as New Zealand analyses. Additionally, some data, such as for natural gas, is not available for New Zealand, either within the GaBi database or from New Zealand sources, in the necessary detail to allow comprehensive environmental impact analysis. This led to the use of natural gas data from other countries, specifically Australia. This, however, introduces significant errors in at least some key impact categories, such as CO_2 emissions associated with natural gas use. New Zealand CO_2 emissions for natural gas use are in the region of 53g CO_2/MJ, as compared to 73 g CO_2/MJ for Australian gas.

The significant variation between New Zealand and European manufacturing, and the resulting data differences, has highlighted the difficulty of using data from one country or region in another country that does not share common manufacturing resources, specifically Europe and New Zealand.

The inherent problem of combining building material manufacturing, and environmental, data from another manufacturing region would ideally be overcome with a comprehensive collection and analysis of New Zealand-specific data.

In the long term, the development of a comprehensive New Zealand Life Cycle Inventory database (which also would include data from other sectors such as transport and energy) would be ideal. One possible way of progressing towards this would be to align methodologies and database structure with the current Australian life cycle inventory initiative (AusLCI). This could contribute to a dataset with a predominance of New Zealand data, appropriate to the balance of local manufacture and internationally sourced materials.

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10 Appendix A1 – Hot spot analysis

10.1 Hotspots in Original Process: DE: Ready Mix Concrete C 20/25

Material: Ready Mix Concrete C20/25		Plan: READY MIX CONCRETE C20/25													
			Plan: PORTLANDCEMENT (CEMI 32,5)												
			Plan: PORTLANDCEMENT GRINDING												
			Plan: CEMENT CLINKER MIX												
Relative contributions from upstream processes to Ready Mix Concrete C20/25		**Gravel 2/32**	**Pulverised lignite**	**Petroleum coke from refinery**	**Hard coal mix**	**Power grid mix**	**Cement clinker mix production (kiln process)**	**Power grid mix**	**Cement bag (paper)**	**Diesel from refinery**	**Fly ash from hard coal power plant**	**Power grid mix**	**Construction machinery (diesel combustion)**	**Transport (several processes)**	**SUM of rel. Contribution**
Priority for replacement / adjustment						x	x	x				x		(global process)	
Inputs	**Primary Energy (non-renewable)**	3,21 %	10,07 %	6,30 %	18,17 %	15,06 %	0,00 %	5,49 %	0,13 %	18,34 %	10,80 %	1,96 %	0,00 %	0,00 %	89,53 %
	Primary Energy (renewable)	6,72 %	1,00 %	0,49 %	0,90 %	47,47 %	0,00 %	17,29 %	4,89 %	1,25 %	0,56 %	6,19 %	0,00 %	0,00 %	86,75 %
	CML2001, Abiotic Depletion Potential (ADP)	2,67 %	11,20 %	7,06 %	20,40 %	10,27 %	0,00 %	3,74 %	0,13 %	20,56 %	12,12 %	1,34 %	0,00 %	0,00 %	89,49 %
Outputs	**CML2001, Global Warming Potential (GWP 100 years)**	1,15 %	0,11 %	0,35 %	1,15 %	5,23 %	74,00 %	1,91 %	0,06 %	0,77 %	5,70 %	0,68 %	0,43 %	4,97 %	96,51 %
	CML2001, Acidification Potential (AP)	2,66 %	0,08 %	0,90 %	1,84 %	4,22 %	58,30 %	1,54 %	0,08 %	2,09 %	4,02 %	0,55 %	2,32 %	13,84 %	92,42 %
	CML2001, Eutrophication Potential (EP)	2,84 %	0,05 %	0,39 %	1,35 %	2,22 %	60,19 %	0,81 %	0,13 %	0,97 %	2,52 %	0,29 %	2,94 %	17,54 %	92,23 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	3,26 %	0,08 %	1,40 %	2,87 %	3,53 %	55,84 %	1,29 %	0,11 %	3,53 %	4,20 %	0,46 %	3,04 %	12,45 %	92,04 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20,00 --> light red numbers: contribution of **10 to 40 %** of the impacts of this category
50,00 --> dark red numbers: contribution of **more than 40 %** of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.2 Hotspots in Original Process: DE: Ready Mix Concrete C 30/37

Material: Ready Mix Concrete C30/37		Plan: READY MIX CONCRETE C30/37	Plan: PORTLANDCEMENT (CEMI 32,5)	Plan: PORTLANDCEMENT GRINDING	Plan: CEMENT CLINKER MIX								
Relative contributions from upstream processes to Ready Mix Concrete C30/37		Gravel 2/32	Pulverised lignite	Petroleum coke from refinery	Hard coal mix	Power grid mix	Cement clinker mix production (kiln process)	Power grid mix	Cement bag (paper)	Diesel from refinery	Construction machinery (diesel combustion)	Transport (several processes)	SUM of rel. Contribution
Priority for replacement / adjustment						X	X	X				(global process)	
Inputs	Primary Energy (non-renewable)	2.74 %	12.11 %	7.58 %	21.84 %	18.10 %	0.00 %	6.59 %	0.15 %	16.97 %	0.00 %	0.00 %	86.08 %
	Primary Energy (renewable)	5.03 %	1.05 %	0.51 %	0.94 %	50.05 %	0.00 %	18.23 %	5.16 %	1.01 %	0.00 %	0.00 %	81.99 %
	CML2001, Abiotic Depletion Potential (ADP)	2.32 %	13.71 %	8.64 %	24.95 %	12.57 %	0.00 %	4.58 %	0.15 %	19.36 %	0.00 %	0.00 %	86.28 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	0.89 %	0.12 %	0.39 %	1.25 %	5.68 %	80.40 %	2.07 %	0.06 %	0.64 %	0.34 %	3.54 %	95.38 %
	CML2001, Acidification Potential (AP)	2.10 %	0.09 %	1.00 %	2.04 %	4.69 %	64.82 %	1.71 %	0.09 %	1.79 %	1.86 %	10.08 %	90.27 %
	CML2001, Eutrophication Potential (EP)	2.23 %	0.05 %	0.43 %	1.50 %	2.45 %	66.49 %	0.89 %	0.14 %	0.82 %	2.35 %	12.69 %	90.04 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	2.59 %	0.09 %	1.56 %	3.21 %	3.95 %	62.47 %	1.44 %	0.12 %	3.04 %	2.46 %	9.12 %	90.05 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20.00 --> light red numbers: contribution of **10 to 40** % of the impacts of this category
50.00 --> dark red numbers: contribution of **more than 40** % of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.3 Hotspots in Original Process: DE: Concrete Roof Tile

Material: Concrete roof tile		Plan: Concrete roof tile						
		Plan: Concrete roof tile (production)					Plan: Concrete roof tile (packaging)	
		Plan: Silica sand	Plan: Electricity					
Relative contributions from upstream processes to Concrete roof tile Functional Unit: *1 kg roof tile*		Silica sand (Excavation and processing)	Power grid mix	Transport sand	color	Portland cement	Packaging film, LDPE	SUM of rel. Contribution
Priority for replacement / adjustment			x			x		
Inputs	Primary Energy (non-renewable)	20,18 %	16,51 %	5,30 %	13,47 %	35,53 %	3,98 %	94,97 %
	Primary Energy (renewable)	13,03 %	65,95 %	0,46 %	16,49 %	1,13 %	1,96 %	99,02 %
	CML2001, Abiotic Depletion Potential (ADP)	22,46 %	11,87 %	6,27 %	13,90 %	35,27 %	4,31 %	94,07 %
Outputs	CML2001, Global Warming Potential (GWP 100 years) *	11,56 %	9,73 %	3,49 %	5,54 %	64,93 %	1,05 %	96,30 %
	CML2001, Acidification Potential (AP)	11,54 %	7,49 %	6,87 %	11,02 %	58,93 %	1,18 %	97,04 %
	CML2001, Eutrophication Potential (EP)	13,86 %	5,31 %	10,66 %	7,12 %	58,99 %	1,14 %	97,09 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	11,89 %	5,04 %	7,25 %	9,20 %	54,71 %	8,06 %	96,16 %

$\underbrace{\hspace{10em}}$

these processes combine to a minimum of 80% of all impacts per considered impact category

***Global Warming Potential:** The production of wood-based construction materials incorporates greenhouse gases such as CO2 and therefore represents a GWP-sink, expressed through negative emissions. These incorporated greenhouse gases are released in the end-of-life of the respective product.

20,00 --> light red numbers: contribution of **10 to 40 %** of the impacts of this category

50,00 --> dark red numbers: contribution of **more than 40 %** of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.4 Hotspots in Original Process: DE: Steel Sheet, galvanized

		Zinc redistilled (Nordenham)	Ferronickel (29%)	Energy from biomass	Power grid mix	Energy from biomass	Ferro manganese (90%; Low Carbon)	Steel plant (electric furnance)	Power grid mix	Natural gas (mix)	Hard Coal	Power grid mix	Thermal energy from natural gas	production steel hot-rolled	SUM of rel. Contribution
Material: Steel sheet, galvanized		Plan: Steel sheet, galvanized													
		Plan: Steel sheet (75mm)													
		Plan: Zink redi	Plan: Crude Steel (electric furnance)												
			Plan: Steel alloy components (FeMn, FeSi, FeNi)												
			Ferro silicon mix (90%)												
			Ferro silicon NO (90%)			Ferro silicon ZA (90%)									
Relative contributions from upstream processes to Steel sheet, galvanized Functional Unit: *1 kg steel sheet*															
Priority for replacement / adjustment					X				X	(X)		X	(X)		
Inputs	Primary Energy (non-renewable)	5.22 %	5.37 %	0.01 %	0.01 %	0.01 %	1.75 %	0.00 %	33.68 %	8.85 %	11.44 %	15.86 %	6.33 %	0.00 %	88.53 %
	Primary Energy (renewable)	10.43 %	0.52 %	15.09 %	17.18 %	10.92 %	0.16 %	0.00 %	27.50 %	0.07 %	0.15 %	12.95 %	0.05 %	0.00 %	95.01 %
	CML2001, Abiotic Depletion Potential (ADP)	5.94 %	6.58 %	0.01 %	0.02 %	0.01 %	2.17 %	0.00 %	26.03 %	11.26 %	14.55 %	12.26 %	8.05 %	0.00 %	86.88 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	3.67 %	7.93 %	-1.35 %	0.09 %	-0.98 %	1.42 %	7.88 %	29.34 %	0.71 %	1.82 %	13.82 %	5.12 %	17.99 %	87.47 %
	CML2001, Acidification Potential (AP)	11.49 %	5.35 %	0.05 %	0.04 %	0.03 %	6.90 %	0.15 %	28.25 %	1.77 %	3.46 %	13.30 %	2.45 %	13.53 %	86.77 %
	CML2001, Eutrophication Potential (EP)	6.70 %	5.30 %	0.09 %	0.06 %	0.06 %	4.49 %	0.30 %	25.79 %	1.57 %	4.44 %	12.15 %	3.72 %	24.49 %	89.16 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	5.64 %	3.23 %	0.17 %	0.02 %	0.12 %	3.18 %	45.83 %	14.56 %	2.38 %	3.33 %	6.86 %	2.27 %	4.31 %	91.89 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20.00 --> light red numbers: contribution of **10 to 40** % of the impacts of this category
50.00 --> dark red numbers: contribution of **more than 40** % of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.5 Hotspots in Original Process: DE: Reinforced Steel (wire)

Material: Reinforced steel (wire)		Plan: Reinforced steel (wire)													
		Plan: Crude Steel (electric furnance)													
		Plan: Steel alloy components (FeMn, FeSi, FeNi)													
		ronickel (Ni 29%)		Ferro silicon mix (90%)											
				Ferro silicon NO (90%)		Ferro silicon ZA (90%)									
Relative contributions from upstream processes to Reinforced steel (wire) Functional Unit: *1 kg wire*		Ferronickel (Ni 29%)	Silica sand (Excavation and processing)	Energy from biomass	Power grid mix	Ferro silicon power grid mix	Energy from biomass	Ferro manganese (90%; Low Carbon)	Steel plant (electric furnance)	Hard Coal mix	Power grid mix	Power grid mix	Thermal energy from natural gas	SUM of rel. Contribution
Priority for replacement / adjustment					x						x	x	(x)	
Inputs	Primary Energy (non-renewable)	0.00 %	0.00 %	0.01 %	0.02 %	2.24 %	0.01 %	2.45 %	0.00 %	4.97 %	47.03 %	17.09 %	13.39 %	87.21 %
	Primary Energy (renewable)	0.00 %	0.00 %	17.53 %	19.96 %	4.56 %	12.69 %	0.18 %	0.00 %	0.05 %	31.95 %	11.61 %	0.09 %	98.61 %
	CML2001, Abiotic Depletion Potential (ADP)	0.00 %	0.00 %	0.02 %	0.03 %	1.05 %	0.01 %	3.27 %	0.00 %	6.84 %	39.37 %	14.30 %	18.44 %	83.34 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	7.12 %	0.00 %	-1.94 %	0.13 %	1.05 %	-1.41 %	2.04 %	11.34 %	0.81 %	42.21 %	15.33 %	11.15 %	87.82 %
	CML2001, Acidification Potential (AP)	2.02 %	0.00 %	0.07 %	0.06 %	4.97 %	0.05 %	10.93 %	0.24 %	1.71 %	44.70 %	16.24 %	5.88 %	86.88 %
	CML2001, Eutrophication Potential (EP)	1.41 %	0.00 %	0.15 %	0.11 %	3.26 %	0.11 %	7.74 %	0.52 %	2.38 %	44.50 %	16.17 %	9.71 %	86.07 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	0.77 %	0.00 %	0.21 %	0.03 %	1.69 %	0.15 %	3.91 %	56.42 %	1.28 %	17.92 %	6.51 %	4.23 %	93.11 %

$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad}_{\text{these processes combine to a minimum of 80\% of all impacts per considered impact category}}$

20.00 --> light red numbers: contribution of **10 to 40** % of the impacts of this category
50.00 --> dark red numbers: contribution of **more than 40** % of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.6 Hotspots in Original Process: DE: Aluminium extrusion profile

Material: Aluminum extrusion profile		Aluminum extrusion profile								
		Aluminium profile	Primary Aluminium							
			Electrolysis				Alumina			
							Alumina 1	Alumina 2		
Relative contributions from upstream processes to Alu. extrusion profile Functional Unit: *1 kg Aluminium*		Power grid mix	Anode production	Power grid mix	Electrolysis	Bauxite mining	Thermal Energy from heavy fuel oil	Power grid mix	Thermal Energy from heavy fuel oil	SUM of rel. Contribution
Priority for replacement / adjustment		X		X				X		
Inputs	Primary Energy (non-renewable)	5,35 %	12,46 %	53,37 %	0,00 %	2,49 %	3,68 %	2,25 %	8,38 %	87,99 %
	Primary Energy (renewable)	0,82 %	0,52 %	94,72 %	0,00 %	0,01 %	0,04 %	0,53 %	0,05 %	96,69 %
	CML2001, Abiotic Depletion Potential (ADP)	4,16 %	15,72 %	46,44 %	0,00 %	3,20 %	4,73 %	1,57 %	10,71 %	86,53 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	4,22 %	4,43 %	43,83 %	20,68 %	2,47 %	3,68 %	1,43 %	8,42 %	89,15 %
	CML2001, Acidification Potential (AP)	1,59 %	4,03 %	32,10 %	17,65 %	6,06 %	17,05 %	1,95 %	8,60 %	89,03 %
	CML2001, Eutrophication Potential (EP)	3,30 %	5,95 %	43,59 %	0,41 %	10,74 %	6,95 %	2,05 %	11,07 %	84,07 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	1,07 %	4,22 %	15,42 %	52,52 %	3,51 %	9,15 %	1,11 %	5,70 %	92,71 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20,00 --> light red numbers: contribution of **10 to 40** % of the impacts of this category
50,00 --> dark red numbers: contribution of **more than 40** % of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.7 Hotspots in Original Process: DE: Emulsion paint, resin-based

Material: Emulsion paint 1kg		Emulsion paint (synthetic resin)								
		Emulsion Paint (Manufacturer 1)				Emulsion Paint (Manufacturer 2)				
Relative contributions from upstream processes to Aluminium Functional Unit: *1 kg Emulsion paint*		Paint (dispersion)	Silicon resin	Styrene acrylate (50%)	Titanium dioxide pigment	Dipropylene glycol	Paint (dispersion)	Styrene butyl acrylate copolymer (50% solid)	Titanium dioxide pigment	SUM of rel. Contribution
Priority for replacement / adjustment										
Inputs	Primary Energy (non-renewable)	0,00 %	0,34 %	15,88 %	30,72 %	2,39 %	0,00 %	12,86 %	23,21 %	85,40 %
	Primary Energy (renewable)	0,00 %	6,26 %	4,88 %	38,31 %	2,07 %	0,00 %	3,43 %	28,94 %	83,90 %
	CML2001, Abiotic Depletion Potential (ADP)	0,00 %	0,30 %	17,19 %	29,52 %	2,35 %	0,00 %	13,99 %	22,31 %	85,66 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	0,00 %	0,37 %	10,84 %	33,79 %	3,47 %	0,00 %	9,36 %	25,53 %	83,34 %
	CML2001, Acidification Potential (AP)	0,00 %	0,08 %	1,25 %	54,13 %	0,38 %	0,00 %	1,01 %	40,90 %	97,74 %
	CML2001, Eutrophication Potential (EP)	0,00 %	0,50 %	8,66 %	34,69 %	5,88 %	0,00 %	6,45 %	26,21 %	82,39 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	15,87 %	0,01 %	1,13 %	1,95 %	0,08 %	78,36 %	0,60 %	1,47 %	99,48 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20,00 --> light red numbers: contribution of **10 to 40** % of the impacts of this category
50,00 --> dark red numbers: contribution of **more than 40** % of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.8 Hotspots in Original Process: DE: Bricks (average)

		Plan: Bricks average					
Material: Bricks (average)							
Relative contributions from upstream processes to Bricks Functional Unit: 1 kg brick		Natural gas mix	Brick production	cellulose / pulp	Wood shavings	Power grid	SUM of rel. Contribution
Priority for replacement / adjustment		(X)				X	
Inputs	Primary Energy (non-renewable)	71,99 %	0,00 %	0,00 %	0,32 %	10,29 %	82,60 %
	Primary Energy (renewable)	0,20 %	0,00 %	0,00 %	94,97 %	3,11 %	98,29 %
	CML2001, Abiotic Depletion Potential (ADP)	41,99 %	44,24 %	0,00 %	0,18 %	3,65 %	90,05 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	5,42 %	159,17 %	-57,64 %	-21,31 %	8,37 %	94,01 %
	CML2001, Acidification Potential (AP)	3,02 %	88,78 %	0,00 %	0,16 %	4,68 %	96,65 %
	CML2001, Eutrophication Potential (EP)	13,24 %	68,60 %	0,00 %	1,10 %	7,95 %	90,89 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	8,44 %	76,67 %	0,00 %	1,50 %	5,21 %	91,82 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20,00 --> light red numbers: contribution of **10 to 40 %** of the impacts of this category
50,00 --> dark red numbers: contribution of **more than 40 %** of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.9 Hotspots in Original Process: DE: Glass Wool (elastic felts)

Material: Glass wool (elastic felts)		Plan: Glass wool (elastic felts)														
		Plan: Glass wool (not cladded)														
		Plan: Fibre		Plan: Glass wool raw fleec				Plan: Melt								
Relative contributions from upstream processes to Glass wool (elastic felts) Functional Unit: *1 kg glass wool*		Power grid mix	Thermal energy from natural gas	Binder glass wool	Glass wool fleec	Power grid mix	Thermal energy from natural gas	Borax penta hydrate	Silica sand (flour)	Soda (Na_2CO_3)	Power grid mix	MWI dry process (average waste)	Power grid mix	Wooden pellets (40% moisture)	SUM of rel. Contribution
Priority for replacement / adjustment		x				x					x		x		
Inputs	Primary Energy (non-renewable)	7,91 %	6,72 %	7,70 %	0,00 %	8,78 %	4,79 %	7,19 %	5,34 %	7,80 %	33,46 %	0,46 %	4,08 %	0,11 %	94,33 %
	Primary Energy (renewable)	8,74 %	0,07 %	1,29 %	0,00 %	9,70 %	0,05 %	0,98 %	4,80 %	0,93 %	36,96 %	0,10 %	4,51 %	30,14 %	98,28 %
	CML2001, Abiotic Depletion Potential (ADP)	6,23 %	8,71 %	9,58 %	0,00 %	6,92 %	6,20 %	11,15 %	4,71 %	9,73 %	26,35 %	0,55 %	3,21 %	0,12 %	93,45 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	7,49 %	5,90 %	3,95 %	0,00 %	8,32 %	4,21 %	9,82 %	5,01 %	12,99 %	31,68 %	4,76 %	3,86 %	-1,99 %	96,00 %
	CML2001, Acidification Potential (AP)	5,96 %	2,34 %	3,42 %	10,92 %	6,61 %	1,67 %	11,10 %	4,04 %	17,07 %	25,20 %	3,78 %	3,07 %	0,25 %	95,42 %
	CML2001, Eutrophication Potential (EP)	3,64 %	2,37 %	9,81 %	16,18 %	4,04 %	1,69 %	14,25 %	2,79 %	20,23 %	15,40 %	2,88 %	1,88 %	0,23 %	95,40 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	2,04 %	1,44 %	2,60 %	60,44 %	2,26 %	1,02 %	5,96 %	1,55 %	9,07 %	8,63 %	1,03 %	1,05 %	0,22 %	97,31 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20,00 --> light red numbers: contribution of **10 to 40** % of the impacts of this category
50,00 --> dark red numbers: contribution of **more than 40** % of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.

10.10 Hotspots in Original Process: DE: Polyethylene foil

Material: Polyethylene foil		Plan: Ethene (ethylene)					Plan: Polyethylene low density granulate		Plan: Polyethylene foil	
Relative contributions from upstream processes to Polyethylene foil Functional Unit: *1 kg foil*		Thermal energy from fuel oil	Natural gas mix	Naphta from refinery	Thermal energy from fuel oil	Thermal energy from fuel oil	Steam Cracker (Europipeline)	Polyethylene low density granulate	Power grid mix	Power grid mix	SUM of rel. Contribution
Priority for replacement / adjustment										x	
Inputs	Primary Energy (non-renewable)	5,41 %	18,86 %	45,22 %	5,52 %	1,37 %	0,00 %	0,00 %	11,62 %	5,59 %	93,60 %
	Primary Energy (renewable)	0,36 %	3,94 %	3,66 %	0,45 %	0,05 %	0,00 %	0,00 %	58,83 %	28,32 %	95,60 %
	CML2001, Abiotic Depletion Potential (ADP)	5,95 %	20,41 %	49,68 %	6,06 %	1,51 %	0,00 %	0,00 %	6,63 %	3,19 %	93,43 %
Outputs	CML2001, Global Warming Potential (GWP 100 years)	13,67 %	5,00 %	13,26 %	13,77 %	3,43 %	0,00 %	3,39 %	19,89 %	9,58 %	82,00 %
	CML2001, Acidification Potential (AP)	5,52 %	6,07 %	25,98 %	9,42 %	1,45 %	0,00 %	0,00 %	28,75 %	13,84 %	91,02 %
	CML2001, Eutrophication Potential (EP)	7,64 %	5,27 %	23,26 %	14,72 %	2,12 %	2,72 %	0,25 %	19,81 %	9,54 %	85,33 %
	CML2001, Photochem. Ozone Creation Potential (POCP)	3,04 %	6,27 %	18,99 %	4,44 %	0,89 %	11,96 %	37,54 %	8,64 %	4,16 %	95,93 %

these processes combine to a minimum of 80% of all impacts per considered impact category

20,00 --> light red numbers: contribution of **10 to 40 %** of the impacts of this category
50,00 --> dark red numbers: contribution of **more than 40 %** of the impacts of this category

Note: In some cases, Processes need parameter-adjustment, rather than replacement of parameters, in some cases, energy carriers need to be replaced by appropriate energy carriers.