IS IT VALID TO USE INTERNATIONAL DATA IN NEW ZEALAND LCA STUDIES?

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ABSTRACT

Environmental life cycle assessment (LCA) is a suitable tool for assessing the environmental performance of a building, a building construction or a building material by taking a systems perspective over the whole life cycle.
Accurate, consistent and relevant data is a key requirement for meaningful LCA studies which can be used in decision making processes of organisations and for policy making. The process of collecting and providing such data is time consuming.
In New Zealand and internationally, a number of databases have been developed for the use in LCA studies of buildings. In this study a LCA of the same house has been conducted based on different life cycle inventory databases. These include two different European databases (GaBi and Ecoinvent), as well as New Zealand specific data, collated by Andrew Alcorn at Victoria University.
The goal of the study was to undertake a scoping study which determines the validity of using international data for LCA studies in the building sector. This is demonstrated by using different databases for the assessment of different design alternatives of a residential building in New Zealand. This includes the ratio of the potential environmental impacts from materials vs. operating energy.

KEYWORDS

LCA, building, databases, comparison

INTRODUCTION

The acceptance of Life Cycle Assessment (LCA) as a useful tool to determine the environmental impacts of the built environment increased significantly over the past few years in New Zealand. The recent discussion document for the Building Code (DBH, 2007) referred explicitly to LCA, at least two building materials manufacturers undertook LCA studies, Beacon has published several papers on LCA (Nebel 2006, Szalay and Nebel 2006) and run LCA workshops in collaboration with the New Zealand Greenbuilding Council, where they attracted 180 stakeholder and BRANZ have run a series of successful LCA workshops in New Zealand as well.

Consistent and relevant data is a key requirement for meaningful LCA studies which can be used in decision making processes and for policy making. The process of collecting and providing such data is time consuming. A study undertaken by Szalay and Nebel (2006) for Beacon came to the conclusion that Alcorn (2003) undertook the most significant and comprehensive LCA-related work on building products in New Zealand. He compiled the embodied energy and CO_2 emissions of about 60 building materials using a mixture of industry and statistical data. Szalay and Nebel (2006) compared Alcorn's data with overseas data and found that New Zealand values were in a range between 20 and 350 % of overseas values. No general tendency could be found: New Zealand data were higher for certain materials and lower for others. Country-specific differences in production processes, or in the electricity mix, for example, can be a reason. Other differences in methodology, boundary conditions and assumptions were also identified. In Szalay and Nebel's study specific data sets for building materials were compared directly and not in the context of a specific building.

In this paper data from three different databases is applied to an existing LCA study (Nebel and Szalay 2007) of a typical New Zealand building in order to analyse the differences based on different datasets. The embodied energy of the same building was calculated using Alcorn's data and European data from the Ecoinvent as well as the GaBi database.

The aim of this paper is to provide a basis for a discussion of the validity of undertaking LCA studies in New Zealand based on consistent international datasets. This was done by testing if the conclusions of a specific case study hold up when different datasets are used for the assessment.

In order to test the applicability of specific European databases in New Zealand an in-depth analysis of these databases would need to be undertaken. This would include the system boundaries, choice of allocation rules, representativeness, as well as the data quality.

METHODOLOGY

The underlying case study and the databases which were used for this paper are briefly described in this section.

Case study

An existing case study has been used and modified for the purpose of this paper. Nebel and Szalay (2007) undertook an LCA study of the "exemplar house" (Willson 2002). This building was specifically designed as an example for research on residential costing and is a two storey design with three bedrooms and a garage with a total floor area of 195 m^2.

The goals of the original study were

- to analyse the ratio of the embodied and operational environmental impacts
- to compare the environmental impacts of six design alternatives of the exemplar house
- to find the environmental hot-spots
- to develop a generic LCA model for further research projects and for communication with stakeholders.

The functional unit of the study was the exemplar house over a 50-year period in New Zealand, based in Wellington and heated with an electric heater in the evening only at a level of 18 °C. The material options included a suspended timber floor or a concrete slab on ground, and timber weatherboard, fibre cement or brick veneer cladding with a concrete tile roof (Table 1)[1].

Table 1: Scenarios in case study considered in this study

Name	Wall cladding	Flooring	Wall framing
WB/CFl/TFr	Weatherboard	Concrete	Timber
BC/CFl/TFr	Brick veneer	Concrete	Timber
FC/CFl/TFr	Fibrecement	Concrete	Timber
WB/TFl/TFr	Weatherboard	Timber	Timber
BC/TFl/TFr	Brick veneer	Timber	Timber
FC/TFl/TFr	Fibrecement	Timber	Timber

The scope of the original study included construction, maintenance, operation and end-of-life. Construction included the manufacturing and transport of the raw materials and products. Transport from producer to the building site and from the building to the landfill was also considered.

Although the analysis in this study is based on the same scope of the study, the data was only updated for the construction phase. The impacts from heating the house were assumed to be the same. New Zealand specific electricity data was already used in the original case study. The operational energy was therefore already based on New Zealand data and not changed in for this analysis.

The material related phases of the life cycle (construction and maintenance) contributed between 40% and 46% of the whole non renewable energy consumption over the whole life cycle in the base scenario (Wellington, evening heating only with electricity). The energy consumption for maintenance was 67% on average over all scenarios.

Data sources

[1] The original study (Szalay and Nebel 2006) included steel as an additional roofing material, two other locations, i.e. Auckland and Queenstown as well as different heating options, i.e. log burner and natural gas.

Datasets from the following data sources were used for the analysis:

Embodied Energy and CO_2 Coefficients

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

GaBi (Germany)

GaBi is professional LCA software for the analysis and optimisation of complex processes and product systems. GaBi is a joint development of LBP[2], University of Stuttgart, and PE Europe GmbH since 1992. A distinctive feature is the visualisation of processes, allowing a quick overview of material, energy, or cost flows, all shown as proportional to quantity of inputs. The GaBi LCA database is well-structured and transparent, with a database on building materials. Most inventories are average German industry data collected by PE Europe between 1996 and 2004. The data is generally regarded to be of high quality. The documentation describes the production process, applied boundary conditions, allocation rules etc. for each product. The database is compliant with the ISO Standards 14040 and 14044.

Ecoinvent (Swiss)

The Ecoinvent databases was provides a consistent set of Life Cycle Inventory data for more than 3500 products and services. The process datasets are transparently documented on the level of unit process inputs and outputs. Data quality is quantitatively reported in terms of standard deviations of the amounts of input and output flows. In many cases qualitative indicators are reported additionally on the level of each individual input and output. The information sources used vary from extensive statistical works to individual (point) measurements or assumptions derived from process descriptions. However, all datasets passed the same quality control procedure and all information relevant and necessary to judge the suitability of a dataset in a certain context is provided in the database. Data documentation and exchange is based on the EcoSpold data format, which complies with the technical specification ISO 14048. Free access to process information via the Internet helps the user to judge the appropriateness of a dataset. The databases has been developed by several Swiss Federal Offices and research institutes. (Frischknecht et al. 2004)

Methodology for comparison

The existing case study by Nebel and Szalay (2007) based on the GaBi database was used as the basis of the analysis. In the next steps Alcorn's (2003) data and the ecoinvent database v1.3[3] were searched for the datasets which match the used materials in the exemplar house best. Most materials were available from Alcorn's publication, but for the following materials no NZ datasets were available:

- particle board
- paint
- paper
- galvanised steel
- carpet
- polyethylene film

The original data used in the case study has been used for those materials.
The ecoinvent database v1.3 provided datasets for all required materials.

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[2] Chair for Building Physics
[3] www.ecoinvent.com, Version 1.3

Due to methodological differences in the calculation of CO_2 emissions in Alcorn's data and the GaBi as well as the Ecoinvent database the comparison was only conducted for embodied energy. The key differences with regard to CO_2 are that Alcorn has taken only CO_2 emissions into account, but no other greenhouse gases, whereas the GaBi database and Ecoinvent include other greenhouse gases such as methane. Alcorn has also included the uptake of CO_2 in biomass and therefore provides negative CO_2 for timber products. CO_2 emissions due to harvesting and manufacturing processes have also been taken into account but are not shown separately in the published data. Taking the CO_2 uptake as negative values into account is regarded as standard practice in LCA, as long as the timber is in use.
In the GaBi database a different approach is taken, which considers the release of CO_2 at the end of life of timber products and therefore shows timber products as "carbon neutral" as a default[4]. The Ecoinvent database does the same. A comparison of the datasets based on CO_2 emissions, or greenhouse gas emissions respectively was therefore not feasible.

After establishing the model with datasets from the two additional data sources the LCA for the "Exemplar House" was calculated. The results were then compared to the original study. Since the aim of this paper was to test the validity of the use of European data in LCA case studies in the building sector the goals of the original study (Nebel and Szalay 2007) were tested with the results of the two new LCA studies (exemplar Alcorn and exemplar Ecoinvent).

RESULTS

The results are provided with regard to each of the goals of the original study as listed below:

- ratio of embodied versus operational impacts
- comparison of design alternatives
- analysis of environmental hotspots
- development of a generic model

Ratio of embodied versus operational impacts

The results for the energy consumption for the construction phase of the six different design options were in the same order of magnitude for all three datasets (Table 2). The operational energy is not affected by the choice of datasets for the materials, and was already in the original study based on New Zealand specific data. This means that the results for the ratio of embodied versus operational energy of the original exemplar house are valid for all three datasets.

Table 2: Energy consumption for the construction phase of the "Exemplar House" for six scenarios, based on three different datasets

	Scenario	WB/TFl/TFr	BC/TFl/TFr	FC/TFl/TFr	WB/CFl/TFr	BC/CFl/TFr	FC/CFl/TFr
Ecoinvent	MJ	244910	250020	263710	267190	274180	285990
Alcorn	MJ	258350	262530	276500	265710	273170	283870
GaBi	MJ	231670	250050	277750	242610	264040	288680

However, no clear trend could be established if the European data leads to higher or to lower results (Figure 1). The results based on GaBi datasets for example produced lower results for the scenario WB/CFl/TFr compared to Scenario BC/CFl/TFr, whereas the Alcorn data produces lower results for the scenario BC/CFl/TFr and higher results for the scenario WB/CFl/TFr. The Ecoinvent data leads in some cases to higher and in other cases to lower results compared to the results based on Alcorn's data. This confirms the results of Nebel and Szalay (2007) who also have established that "no general tendency could be found: New Zealand data were higher for certain products and lower for others."

[4] The CO_2 uptake can be added manually in the GaBi datasets.

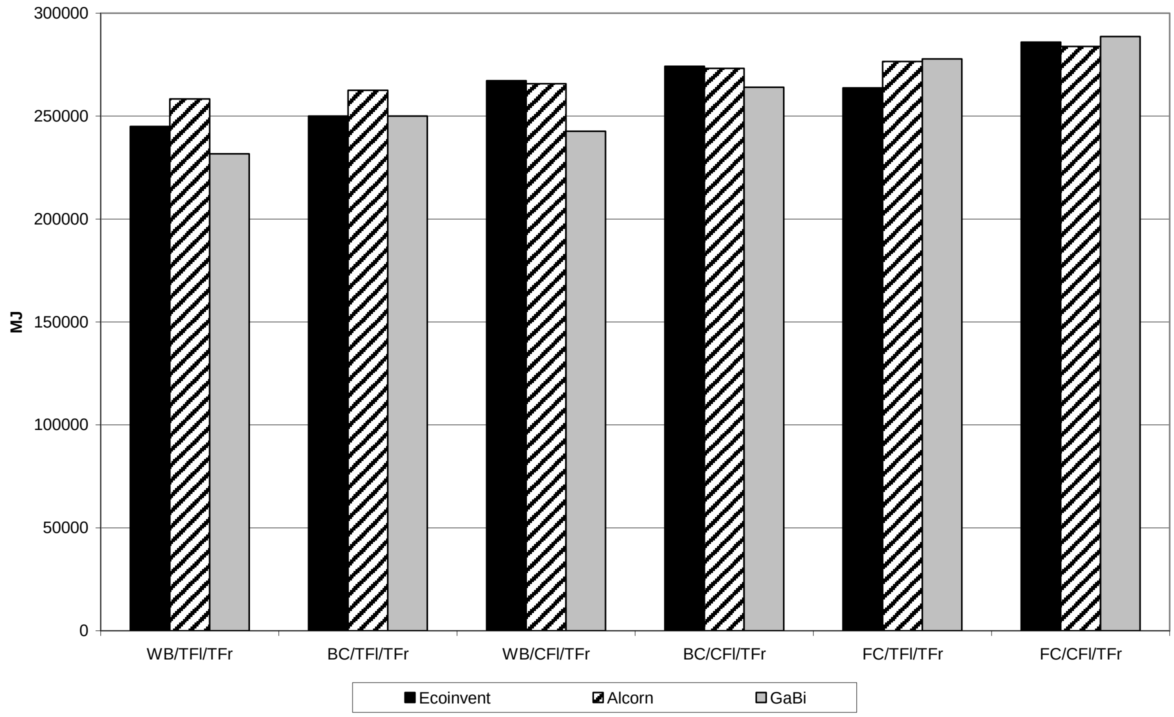

Figure 1: Energy consumption for the construction of the exemplar house based on three different datasets

Comparison of design alternatives

As shown in Figure 1 the scenarios rank differently dependent on the dataset used for the analysis. Based on GaBi data the scenario WB/CFl/TFr for example has a lower embodied energy than the Scenario BC/TFl/TFr. Based on Ecoinvent data the results are the opposite.
In order to show the results of the comparison more clearly, the scenarios have been ranked for each of the datasets (Table 3). The scenarios have been named as follows for an easier interpretation:

A - WB/TFl/TFr
B - BC/TFl/TFr
C - FC/TFl/TFr
D - WB/CFl/TFr
E - BC/CFl/TFr
F - FC/CFl/TFr

Table 3: Ranking of scenarios based on different datasets

Ranking	Ecoinvent	Alcorn	GaBi
1	A	A	A
2	B	B	D
3	C	D	B
4	D	E	E
5	E	C	C
6	F	F	F

Based on all three datasets the Scenario A (Weatherboard/Timber Floor/Timber frame) had the lowest embodied energy and Scenario F (Fibre Cement cladding/Concrete Floor/Timber frame) had the highest embodied energy. However, these results have to be treated with care, since the differences to the other

scenarios are not significant. The embodied energy for Scenario C (Alcorn) is for example only 2.5 % lower than for Scenario F which will be within the uncertainty of the used datasets.
The ranking also shows that comparing the results based on the two European databases the results are not closer to each other then comparing it with the New Zealand database. Scenario B for example ranks the same based on Ecoinvent data and on Alcorn's data, whereas Scenario E and C rank the same based on GaBi data and on Alcorn's data.

Analysis of environmental hot spots

For the test of this goal the only the key components, foundation, floor, wall and roof of the house were analysed. The contribution of those 4 components together to the complete construction varies from 71% to 76%. The relationships of these four components to each other are shown in more detail in Figure 2.

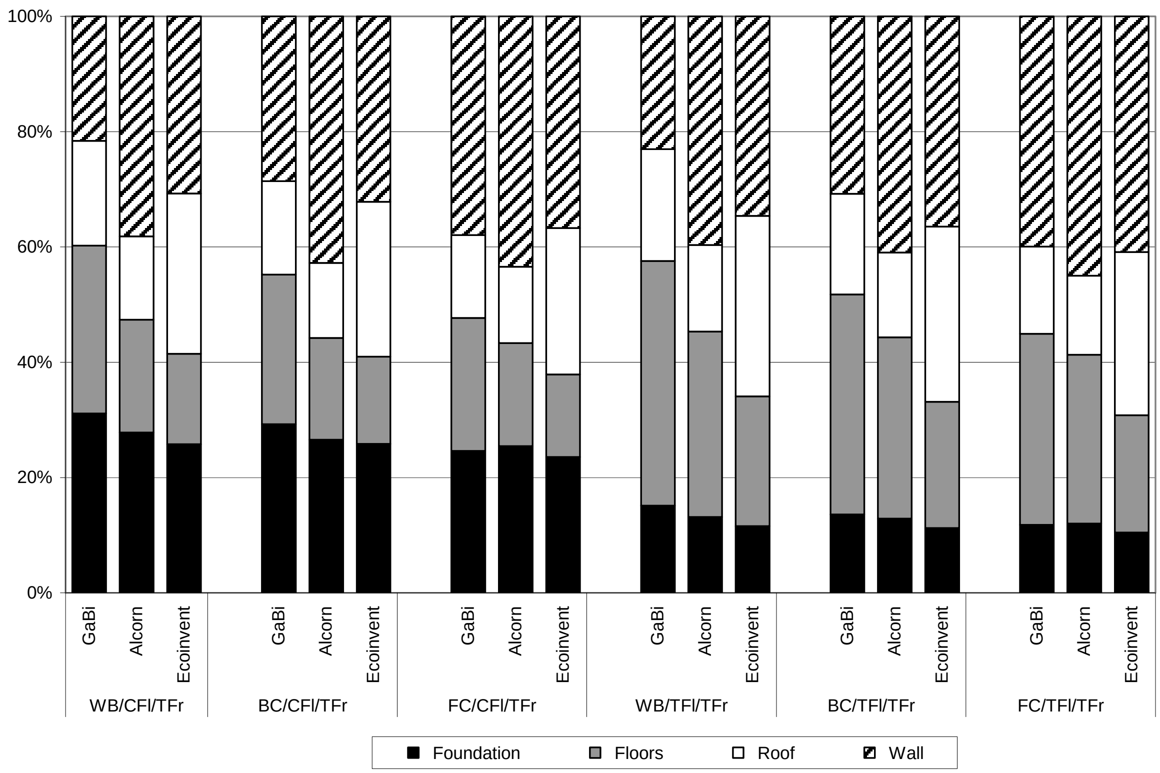

Figure 2: Relationship of four key building components to each other

The contribution of the foundation to the four key components is similar in the results based on all three datasets. The results of the flooring system are similar based on Alcorn's data and Ecoinvent data for concrete slab. Wall systems contribute around 40 % in most cases, but only around 20 % for the Weatherboard scenarios based on GaBi Data.
These results show that there are great differences between the various datasets.
The embodied energy for fibre glass insulation based on Alcorn's data is for example 32 MJ/kg and 41 MJ/kg in the GaBi database. According to the GaBi database cement has an embodied energy of 4 MJ/kg, whereas Alcorn states 6 MJ/kg. These examples show that a hot spot analysis can not be undertaken in detail based on different datasets.

Development of generic LCA model

A generic LCA model for a house can be developed based on any of the three analysed datasets, provided that the materials are available in the database. However, the application of the model can be restricted based on the underlying data. This paper has for example focussed on embodied energy only, because this was the only indicator which could be assessed based on the tree different datasets. However, embodied energy as such is not an environmental impact. The emissions related to the provision of the energy cause environmental impacts such as global warming, acidification or eutrophication as well as ozone depletion. These environmental impacts should therefore be considered in an environmental assessment. The requirement for this is that the datasets used in the LCA model provide the information on these emissions. Global warming is currently regarded as the most important environmental issue by most people, but there is no scientifically basis for this rating, i.e. some people might think that ozone depletion is more important. Providing results for other environmental impacts reduces therefore the value judgement in the presentation of the results.

Szalay and Nebel (2006) have also looked into the comparison of greenhouse gases versus the consideration of only CO_2 emission. They found that the difference between the CO_2 emissions and the total global warming potential is on average 5-10 % for building materials. However, if renewable materials, for example sheep wool for insulation are taken into account, greenhouse gases such as methane and nitrous oxides need to be taken into account because they constitute over 80% of farm-related GHG emissions. This shows that it is important to take other greenhouse gases into account and not to limit the results to CO_2 emissions.

CONCLUSIONS

The results of this analysis have shown that country specific data is essential for detailed analysis and design recommendations. The results of an environmental hot spot analysis based on international data have to be interpreted cautiously. If the hot spots for example do not show outstandingly high results, they might not be ‘hot spots’ if the results are based on national data. Very detailed design implications or the use of specific materials should therefore not be based on international data. However, this is only relevant if the materials are actually manufactured locally.

The development of generic models which demonstrate the importance of embodied energy and operational energy respectively can be based on international data. The overall results were in a very similar range for all three datasets. A model based on international data can also be used without restrictions to communicate the generic benefits of the LCA approach and to demonstrate how potential results might look like. The underlying data is not critical for this application of an LCA study, as long as the data set is consistent and does not lead to unrealistic results.

One of the most important aspects by using international data, or any data for an LCA study, is that the dataset is consistent. That means that for example the same system boundaries are applied and the data is of the geographic origin needed in the model.

For an environmental assessment it is also important that the methodologies for the assessment are considered, i.e. that all greenhouse gases are taken into account and the emissions for other environmental impacts are provided. It is also useful to be able to differentiate between renewable and non-renewable energy. These aspects should be considered when national data is collected.

The key conclusion from this analysis is that a national database for building materials would be required if LCA should be used effectively for design recommendations in the built environment.

LITERATURE

Alcorn, A. 1995. Embodied energy coefficients of building materials. Centre for Building Performance Research. Victoria University of Wellington.

Alcorn, A. 1998. Embodied energy coefficients of building materials. Centre for Building Performance Research. Victoria University of Wellington.

Alcorn, A. 2003. Embodied energy and CO2 coefficients for NZ building materials. Centre for Building Performance Research. Victoria University of Wellington.

Nebel, B. 2006. White Paper – Life Cycle Assessement and the building and construction industry. Prepared for Beacon Pathway Limited.

DBH 2007: Building Code Review Consultation 2007. Wellington.

Frischknecht et al. 2004. Frischknecht R, Jungbluth N, Althaus H-J, Doka G, Dones R, Heck T, Hellweg S, Hischier R, Nemecek T, Rebitzer G, and Spielmann M (2004): The ecoinvent Database: Overview and Methodological Framework. Int J LCA, OnlineFirst DOI: http://dx.doi.org/10.1065/lca2004.11.181.1

GaBi: LBP, PE: GaBi 4. Software-System and Databases for Life Cycle Engineering. Copyright, TM. Stuttgart, Echterdingen

Nebel, B.; Szalay, Z. 2007. The Exemplar House - a generic LCA model for houses in New Zealand. Proceedings. 2nd International Conference on Sustainability Engineering and Science. 20-23 February 2007, Auckland, New Zealand.

Szalay, Z.; Nebel, B. 2006: Analysis of currently available environmental profiles of building products. Report TE200. Prepared for Beacon Pathway Limited.

Willson, R.J. 2002. The exemplar house. A specific example of residential costing. Plans and Specifications Ltd.