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CASE STUDY

Life cycle assessment of commercial furniture: a case study of Formway LIFE chair

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Abstract

Background, aims and scope The environmental aspects of companies and their products are becoming more significant in delivering competitive advantage. Formway Furniture, a designer and manufacturer of office furniture products, is a New Zealand-based company that is committed to sustainable development. It manufactures two models of the light, intuitive, flexible and environmental (LIFE) office chair: one with an aluminium base and one with a glass-filled nylon (GFN) base. It was decided to undertake a life cycle assessment (LCA) study of these two models in order to: (1) determine environmental hotspots in the life cycle of the two chairs (goal 1); (2) compare the life cycle impacts of the two chairs (goal 2); and (3) compare alternative potential waste-management scenarios (goal 3). The study also included sensitivity analysis with respect to recycled content of aluminium in the product.

Materials and methods The LIFE chair models consist of a mix of metal and plastic components manufactured by selected Formway suppliers according to design criteria. Hence, the research methodology included determining the specific material composition of the two chair models and acquisition of manufacturing data from individual suppliers. These data were compiled and used in conjunction with pre-existing data, specifically from the ecoinvent database purchased in conjunction with the SimaPro7 LCA software, to develop the life cycle inventory of the two chair models. The life cycle stages included in the study extended from raw-material extraction through to waste management. Impact assessment was carried out using CML 2 baseline 2000, the methodology developed by Leiden University's Institute for Environmental Sciences.

Results This paper presents results for global warming potential (GWP100). The study showed a significant impact contribution from the raw-material extraction/refinement stage for both chair models; aluminium extraction and refining made the greatest contribution to GWP100. The comparison of the two LIFE chair models showed that the model with the aluminium base had a higher GWP100 impact than the model with the GFN base. The waste-management scenario compared the GWP100 result when (1) both chair models were sent to landfill and (2) steel and aluminium components were recycled with the remainder of the chair sent to landfill. The results showed that the recycling scenario contributed to a reduced GWP100 result. Since production and processing of aluminium was found to be significant, a sensitivity analysis was carried out to determine the impact of using aluminium with different recycled contents (0%, 34% and 100%) in both waste-management scenarios; this showed that increased use of recycled aluminium was beneficial. The recycling at end-of-life scenarios was modelled using two different end-of-life allocation approaches, i.e. consequential and attributional, in order to illustrate the variation in results

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caused by choice of allocation approach. The results using the consequential approach showed that recycling at end-of-life was beneficial, while use of the attributional method led to a similar GWP100 as that seen for the landfill scenario.
Discussion The results show that the main hotspot in the life cycle is the raw-material extraction/refinement stage. This can be attributed to the extraction and processing of aluminium, a material that is energy intensive. The LIFE chair model with the aluminium base has a higher GWP100 as it contains more aluminium. Sensitivity analysis pertaining to the recycled content of aluminium showed that use of aluminium with high recycled content was beneficial; this is because production of recycled aluminium is less energy intensive than production of primary aluminium. The waste-management scenario showed that recycling at end-of-life resulted in a significantly lower GWP100 than landfilling at end-of-life. However, this result is dependent upon the modelling approach used for recycling.
Conclusions With respect to goal 1, the study found that the raw-material extraction/refinement stage of the life cycle was a significant factor for both LIFE chair models. This was largely due to the use of aluminium in the product. For goal 2, it was found that the LIFE chair model with the aluminium base had a higher GWP100 than the GFN model, again due to the material content of the two models. Results for goal 3 illustrated that recycling at end-of-life is beneficial when using a system expansion (consequential) approach to model recycling; if an attributional 'cut-off' approach is used to model recycling at end-of-life, there is virtually no difference in the results between landfilling and recycling. Sensitivity analysis pertaining to the recycled content of aluminium showed that use of higher recycled contents leads to a lower GWP100 impact.
Recommendation and perspectives Most of the GWP100 impact was contributed during the raw-material extraction/refinement stage of the life cycle; thus, the overall impact of both LIFE chair models may be reduced through engaging in material choice and supply chain environmental management with respect to environmental requirements. The study identified aluminium components as a major contributor to GWP100 for both LIFE chair models and also highlighted the sensitivity of the results to its recycled content. Thus, it is recommended that the use of aluminium in future product designs be limited unless it is possible to use aluminium with a high recycled content. With respect to waste management, it was found that a substantial reduction in the GWP100 impact would occur if the chairs are recycled rather than landfilled, assuming an expanding market for aluminium. Thus, recycling the two LIFE chair models at end-of-life is highly recommended.

Keywords Carbon footprint · Case study · Commercial furniture · LIFE chair · LCA · Life cycle assessment · Office furniture

1 Introduction

In the office furniture sector, manufacturers are increasingly required to provide information on the environmental performance of their products. The Australian and New Zealand corporate and government sectors are moving towards including environmental sustainability considerations as key elements of their procurement policies. Therefore, the availability of product ecolabel certification and/or sound environmental product declarations (EPD; Fet and Skaar 2006) is increasingly necessary to maintain commercial competitiveness while avoiding claims that may be perceived as greenwash (Soanes and Stevenson 2005). Design for environment (DfE), cleaner technologies and life cycle assessment (LCA; SETAC 1993; Guinée et al. 2002; Udo de Haes et al. 1999a, b; Todd and Curran 1999) tools and approaches have long been used to minimise the environmental impacts of production and assist in creating environmentally preferable products. Within the commercial office furniture sector, companies such as Herman Miller (Rossi et al. 2006) and Steelcase (2004) have carried out environmental studies based on DfE and LCA. Additionally, a recent Norwegian project has developed Product Category Rules (PCR) for EPDs based on LCA (EPD 2005). Some public EPD declarations according to PCR, including office furniture, are publicly available (Fet and Skaar 2006; EPD 2005; NHO 2006).

Formway Furniture is an office furniture designer and manufacturer based in Wellington, New Zealand. The company is committed to improving its environmental performance to ensure that its products and processes are aligned with sustainability principles. Formway's product, the light, intuitive, flexible and environmental (LIFE) chair, was designed during 1997/1998 with environmental sustainability principles incorporated into the product during the design process. The product design concept also effectively incorporated the 'Reduce, Reuse, Recycle' eco-design (Lewis et al. 2001) principles. The LIFE chair and its specific material components are shown in Fig. 1.

The purpose of this research was to develop an in-depth understanding of the environmental impacts associated with the LIFE chair's life cycle. The resulting information will be used to improve the product's environmental performance as part of Formway's environmental sustainability programme and also to provide direction for new designs.

2 LIFE LCA

2.1 Methodology and framework

Since the LIFE chair is manufactured from components supplied by numerous suppliers, the LCA study required

Fig. 1 LIFE chair material components

	Component	Material
1 -	Mesh back	Polyester
2 -	Back frame	Glass filled nylon
3 -	Lumbar	ABS
4 -	Lumbar hinge	Nylon
5 -	Arm	Aluminium
6 -	Arm pads	Polyurethane foam
7 -	Arm components	Acetal
8 -	Seat cushion	Polyurethane foam
9 -	Seat moulding	Hytrel Crastin(PBT)
10 -	Seat carriage	Aluminium
11 -	Mechanism assembly	Aluminium
12 -	Gas spring tube	Steel
13 -	Base	Nylon / aluminium
14 -	Castors	Nylon
15 -	Castor axle, spring	Zinc
	Springs, bolts, pivots	Steel

information on materials and processes to be gathered from within Formway and from suppliers as shown in Fig. 2. The process information from within Formway was gathered by audits, and questionnaires were used to obtain supplier information.

One significant outcome of the questionnaires was that, in addition to the process information collected, the level of responses gave an indication of each supplier's environmental awareness, application of cleaner production strategies and achievement of environmental standards such as International Standards Organisation (ISO)14001 (ISO 2004). It was generally found that the internationally based companies were more responsive to the questionnaires and provided a high level of information. However, some of the smaller suppliers, including those located in New Zealand,

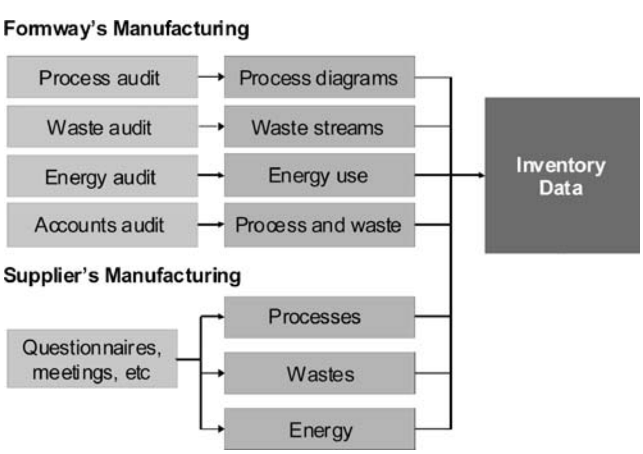

Fig. 2 Source of industry-specific data during production of components, assembly and packaging of chairs

did not have documented information on their materials and processes. This is due, in part, to the lack of pressure from government or customers requesting such information.

As described in the International Standards Organisation's LCA framework (ISO 1997), the LCA framework includes four phases: goal and scope definition, inventory analysis, impact assessment and interpretation. The first three phases are described in Sections 2.2 to 2.4, and interpretation is the subject of Sections 3 and 4.

2.2 Goal, scope and functional unit

(1) Goal

The aim of the study was to develop a better understanding of the life cycle environmental impacts associated with the LIFE chair. The specific goals of the study were to:

1. Determine environmental hotspots in the life cycle of the two models of LIFE chair [one with aluminium base and the other with glass-filled nylon (GFN) base]
2. Compare the life cycle environmental impacts of the two models of LIFE chair
3. Compare alternative potential waste-management scenarios for the two models of LIFE chair

The first and second goals inform Formway's environmental design improvement initiatives by providing detailed information about the environmental impacts of each chair model. The third goal was identified as a specific focus within the LCA study because Formway is actively investigating the best end-of-life (EOL) strategy for the LIFE chairs as part of a company stewardship programme. Initially, a streamlined version of this LCA study (Babarenda Gamage

and Boyle 2006) was conducted using EcoIndicator99 methodology, and this was extended to the study reported in this paper which includes all life cycle stages. Furthermore, sensitivity analysis was carried out to determine sensitivity to aluminium recycled content.

(2) Scope

The aim of the study was to include all possible processes from cradle to grave within practical limitations. The inventory of inputs and outputs of the product therefore included the following stages:

–Extraction of raw materials from the Earth's crust and subsequent refining to commercial quality
–Utilisation of raw materials to manufacture components supplied by Formway's suppliers
–Transportation of the components from the sites of manufacture to the Formway production facility in Wellington, New Zealand
–Assembly and packaging of the LIFE chair
–Transportation of manufactured products from Formway to the customer
–Use phase and waste management

Figure 3 indicates the processes included in this study. The main inventory assumptions were:

–Aluminium with the world average recycled content of 34% (Bertram 2006) was used for both the aluminium and GFN base chairs.

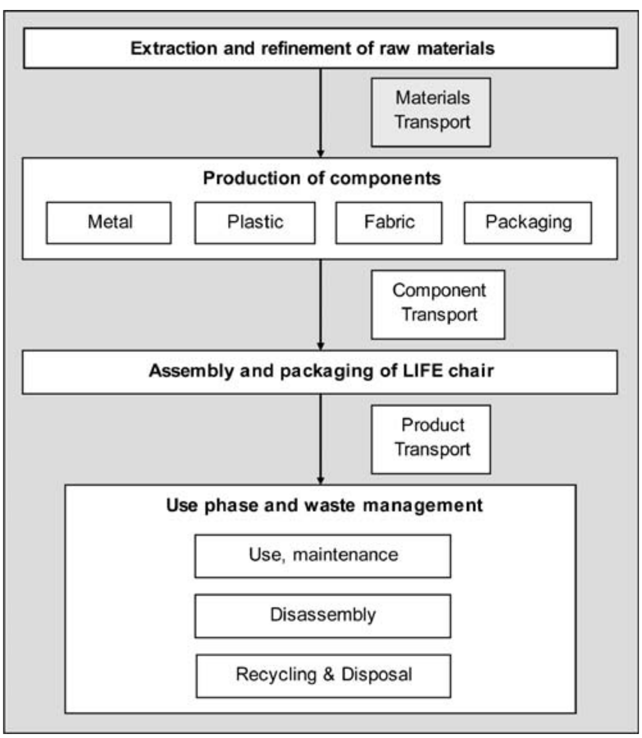

Fig. 3 LIFE LCA system boundary

–An average recycled content of 20% for steel components was used in both chairs (with validation from suppliers).
–Polyethylene terephthalate, which was used as a proxy for Hytrel-crastin, is expected to display similar environmental effects as Hytrel-crastin.
–The customer was considered to be in Sydney, Australia, as this would represent an average-case scenario for transport.

(3) Functional unit

The function of the LIFE chair is to provide stable, ergonomic, seating support for an office workstation. The functional unit for one LIFE chair was defined as provision of comfortable office seating, with the features stated in the product description (Formway 2004) considered over a period of 10 years in line with the product warranty.

2.3 Inventory analysis

There are two distinct models of the LIFE chair: one has an aluminium base, and one has a glass-filled nylon base. The two models weigh approximately 18 and 17 kg, respectively. The percentage material composition for the two chair models is given in Table 1. The most significant difference between the two LIFE models is their aluminium and GFN contents: the aluminium base model has approximately 2 kg more aluminium by weight than the GFN base model, and the GFN base model has

Table 1 Material composition for the LIFE chair models with aluminium and GFN bases

Material	LIFE % weight components	
	Aluminium base model	GFN base model
Aluminium	59.3	49.8
Steel	9.1	9.6
Glass filled nylon	6.3	15.6
Polypropylene	0.8	0.9
Glass filled polypropylene	0.3	0.3
PUR (polyurethane)	4.6	4.8
POM (Acetyl)	1.8	1.9
Acrylonitrile butadiene styrene	2.1	2.2
Fabric	0.8	0.8
Hytrel-crastin [polybutylene terephthalate (PBT)]	7.1	7.6
PA6 (nylon)	2.2	2.3
Packaging	5.7	4.2
Total	100	100

Table 2 Origin of components

Material	Location of component manufacture	
	Aluminium base model	GFN base model
Aluminium	58% USA 41% China 1% New Zealand	72% USA 27% China 1% New Zealand
GFN	100% USA	43% USA 57% Australia
Mesh/fabric	100% Germany	100% Germany
Steel	8% New Zealand 92% China	8% New Zealand 92% China
Hytrel-crastin	100% New Zealand	100% New Zealand
Other plastics	5% New Zealand 95% USA	5% New Zealand 95% USA

approximately 1.5 kg more GFN than the aluminium base model.

For the study, data were used directly from suppliers where possible. Where supplier data were unavailable, databases in SimaPro7, specifically the ecoinvent v1.3 database (Frischknecht et al. 2005), were used directly with modifications to the source of electricity supply. The reason for the modification is that ecoinvent consists primarily of European data, whereas Formway materials come from New Zealand, Australia, China, Germany and USA (which have different electricity mixes). Table 2 shows the percentage source of materials for this study. The electricity modifications were deemed sufficient to reflect the process data for Formway suppliers. All data pertaining to the raw materials, transport, packaging and the EOL stages are from data found within the ecoinvent database. The data on component production were based on industry-specific data gathered from within Formway supplemented by literature data where necessary. If possible, data for the relevant time periods were also chosen. Further descriptions of inventory data and assumptions are given in Appendix 1.

2.4 Impact assessment

Impact assessment was carried out using SimaPro7 LCA software by PRé Consultants (Pré Consultants 2006), employing CML 2 baseline 2000 methodology (Guinée et al. 2000). For the purpose of this paper, only characterisation results for Global Warming Potential (GWP100) are presented. This category was chosen for two reasons: (1) global warming is a significant issue for businesses and the environment, and (2) other categories follow a similar pattern of results as the GWP100 category.

3 LCA results

The results in this section are presented according to each of the goals outlined in Section 2.2. The GWP100 results are presented as a percentage relative to the total GWP100 of the LIFE chair model with the aluminium base. Note that results showing the nine default impact categories as per CML 2 for the baseline case are included in Appendix 2.

3.1 Goal 1: determine hotspots in the life cycle

Figure 4 gives the results for the baseline case for both chair models; the results include all the life cycle stages discussed above, use the average aluminium recycled content (34%), and model landfilling for the waste-management scenario. The results clearly show that the raw-material extraction/refinement and component production stages contribute to the majority of the GWP100 result.

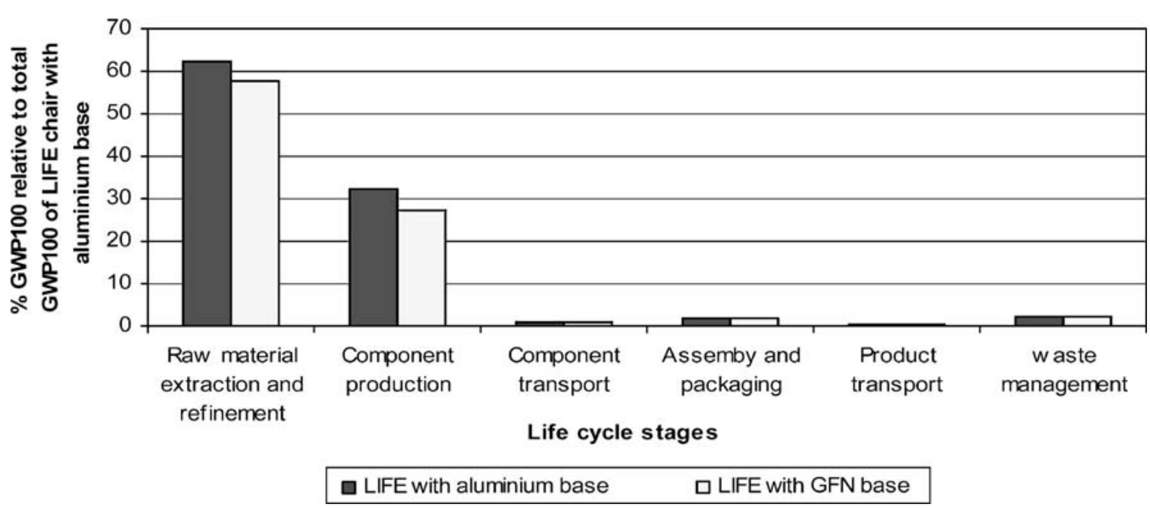

Fig. 4 Percent GWP100 results for the life cycle stages of the two LIFE chair models relative to LIFE chair with aluminium base

However, the raw-material extraction/refinement stage is of most significance, contributing over half of the total GWP100 impact for both LIFE chair models. The two transport stages and the waste-management stage make a negligible contribution to the GWP100 result. Thus, the raw-material extraction/refinement stage was investigated further to determine the material responsible for this impact contribution as shown in Fig. 5.

It can be seen that aluminium is the major contributor to the GWP100 impact. For the LIFE chair model with the aluminium base, aluminium is responsible for approximately 78% of the GWP100 impact at the raw-material extraction/refinement stage. Aluminium contributes to 59% and 50% of the total weight of the aluminium and GFN base chair models, respectively, and it also has a relatively high energy requirement to produce; therefore, it is not surprising that environmental impact from aluminium dominates the raw-material extraction/refinement stage.

3.2 Goal 2: comparison of LIFE chair models

The LIFE chair model with the aluminium base had a 10% higher GWP100 result than the GFN base model over the entire life cycle (see Fig. 4). Figure 4 shows that the main difference between the two LIFE chair models occurs at the raw-material extraction/refinement and component production stages. The difference at the raw-material/extraction stage is due to the difference in the aluminium and GFN contents of the two chairs (as noted above). The difference in aluminium and GFN content is also reflected at the component production stage.

3.3 Goal 3: waste management

With respect to waste management, both chairs are technically over 90% recyclable; however, this study compares the two EOL scenarios where (1) the entire chair (including packaging) is landfilled, and (2) metal components are recycled, and the remainder of the chair is landfilled. The recycling scenario was modelled by means of system expansion (ISO 2006; Ekvall and Weidema 2004; ISO 1999); it was assumed that there is an expanding market for aluminium so that the recycling of aluminium primary displaces aluminium production. The transport of components to the nearest landfill/recycling facility is also included.

The results from the comparison of EOL processes are given in Fig. 6.

The results indicate that landfilling results in a similar GWP100 impact at the waste-management stage for both LIFE chair models. For recycling at EOL, there is a net negative GWP100 for the two chair models. This avoided impact can be thought of as the avoided burdens from recycling aluminium materials in relation to the production of primary aluminium. Since there is more aluminium in the LIFE chair model with the aluminium base, it has more avoided impact. With regard to recycling, the benefits of recycling both LIFE chair models clearly outweigh the additional impact generated from transport to recycling facilities.

With respect to goal 2, the difference between the total GWP100 for the entire life cycle of the two LIFE chair models with landfilling at EOL was found to be approximately 10%, and the LIFE chair model with the aluminium base had the higher impact. When the two models are recycled, there is a negligible difference between them because the benefits of recycling the aluminium mitigate the higher use of aluminium in the chair with the aluminium base. Thus, the investigation of the waste-management options indicates that recycling at EOL is fundamental in reducing the net GWP100 impact of both LIFE chair models.

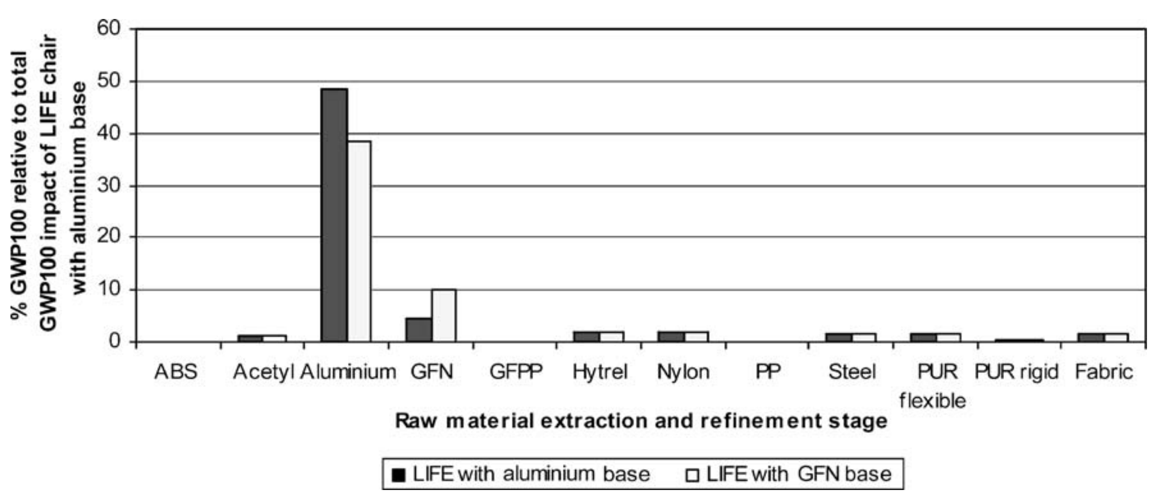

Fig. 5 Percent GWP100 results from raw-material extraction and refinement stage relative to LIFE chair with aluminium base

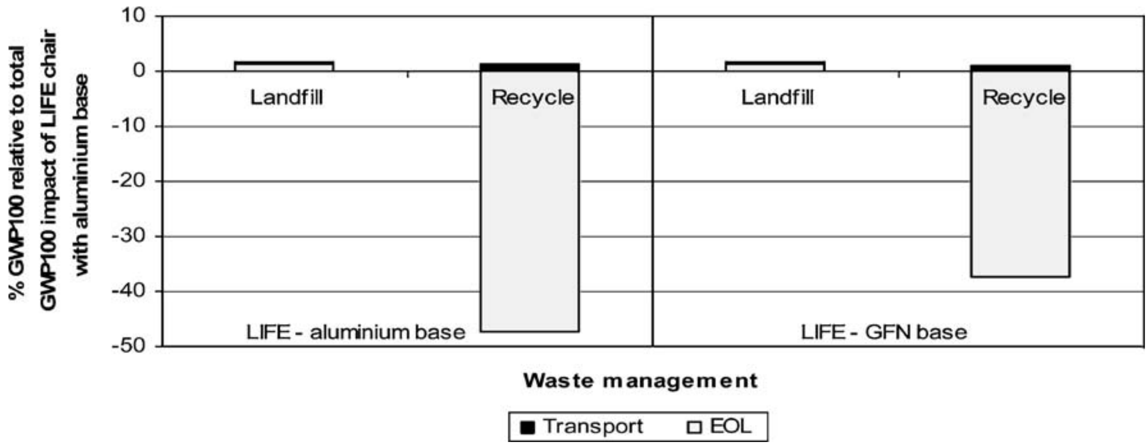

Fig. 6 Percent GWP100 results from waste-management stage considering landfill versus recycling relative to LIFE chair with aluminium base

3.4 Sensitivity analysis

Since production and processing of aluminium is a major contributor to GWP100 in the study, sensitivity analysis was carried out to determine the relative effect of recycled aluminium content on the results. Three scenarios were modelled representing: (1) primary aluminium use (P), (2) 34% recycled aluminium—baseline case (RA1), and (3) 100% recycled aluminium (RA2). The three scenarios represent three potential real-life situations as the recycled content in aluminium is based on factors such as spot price and supplier decisions. Figure 7 shows that, when considering both the landfill and recycling options, the GWP100 impact decreases dramatically with increased recycled content of aluminium for both chairs. For landfilling at EOL, the GFN base model has a lower GWP100 than the aluminium base model for all three recycling scenarios; however, for recycling at EOL, the aluminium base model has an equivalent or lower GWP100 compared with the GFN base model for all three scenarios. For the RA2 scenario, recycling at EOL gives a net negative GWP100 result for the aluminium base model; as noted above, such a result is only valid if there is an expanding market for aluminium when the chair is recycled at EOL.

A further issue concerns how to model recycling of aluminium at EOL, as there is no expert consensus on a single method for treating the allocation issues that arise at recycling (Klöpffer 1996). In the baseline study, system expansion was used because it is the preferred approach in the ISO LCA standards (ISO 1999); approaches based on similar principles have been applied for paper recycling (Weidema 2001; Ekvall and Finnveden 2000). However,

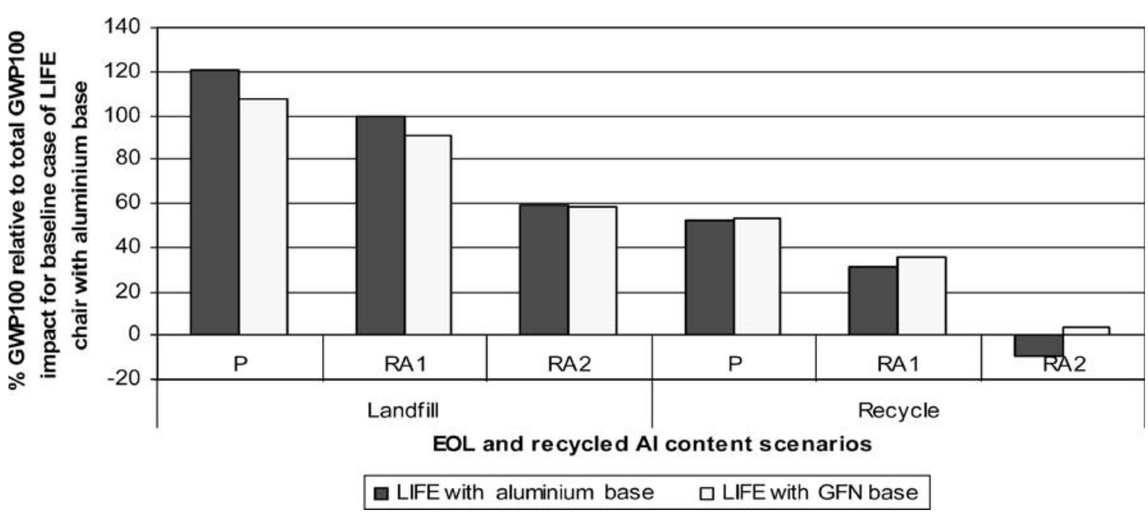

Fig. 7 Percent impact of different aluminium recycled content on the total life cycle of the two chair models relative to LIFE chair with aluminium base using 34% recycled aluminium content

two different approaches, consequential versus attributional, also known as avoided burdens versus partitioning and prospective versus retrospective (Ekvall and Weidema 2004; Weidema 2001; Heijungs and Guinée 2007), are acknowledged by LCA practitioners. Ekvall and Weidema (2004) state that the consequential approach “is likely to result in more comprehensive and accurate information about the consequences of buying a product.” However, Heijungs and Guinée (2007) argue that the speculative reasoning required for the consequential LCA approach means that such LCAs would become “more incredible and disputable”. The system expansion approach used in the baseline study is a consequential approach, and so it was decided to instead investigate the influence on the results of using an attributional approach. The attributional approach used was the ‘cut-off’ method (Baumann and Tillman 2004, p. 82): collection and transport of aluminium to the recycling facility is attributed to the LIFE chair, while the impacts from the recycling process are attributed to a subsequent product. The total GWP100 considering the sum of all life cycle stages for the three aluminium recycled contents using the attributional method is given in Fig. 8; note that these figures compare the percentage GWP100 relative to the total life cycle GWP100 from the baseline case (34% recycled aluminium content and landfilling at EOL) of the LIFE chair model with the aluminium base. It can be seen that there is almost no difference between landfilling and recycling scenarios when using the attributional method; this is because the LIFE chair does not receive any credit for its contribution of aluminium scrap to the market when recycling at EOL.

Interestingly, the consequential approach to recycling yields results that give a strong incentive for recycling aluminium at EOL (see Fig. 7). However, since the attributional approach gives results for the recycling scenario that are nearly equivalent to the landfill scenario, it provides no incentive for recycling at EOL (see Fig. 8).

4 Conclusions and recommendations

The study found that the raw-material extraction/refinement stage of the life cycle was significant for both LIFE chair models. The baseline case showed that the GWP100 impact from transport and waste management (landfilling) was negligible compared to the raw-material extraction/refinement stage. Investigation of the raw-material extraction/refinement stage showed that aluminium was the main contributor to the high GWP100 in both chair models. When comparing the overall life cycle; the chair model with the aluminium base had a higher GWP100 than the GFN model; this is directly attributed to the material content of the two chair models. The waste-management scenario comparing landfilling and recycling illustrated the benefits of recycling at EOL; since there was more aluminium available for recycling in the LIFE chair model with the aluminium base, it yielded a higher avoided impact than the GFN base model. Sensitivity analysis pertaining to the recycled content of aluminium showed that a higher recycled content led to a lower GWP100 impact.

When considering recycling at EOL, the consequential approach yielded results that gave an incentive for recycling at EOL (compared with landfilling). However, the attributional method showed that recycling at EOL gave a similar GWP100 as landfilling. These results show the importance of the modelling approach used for recycling:

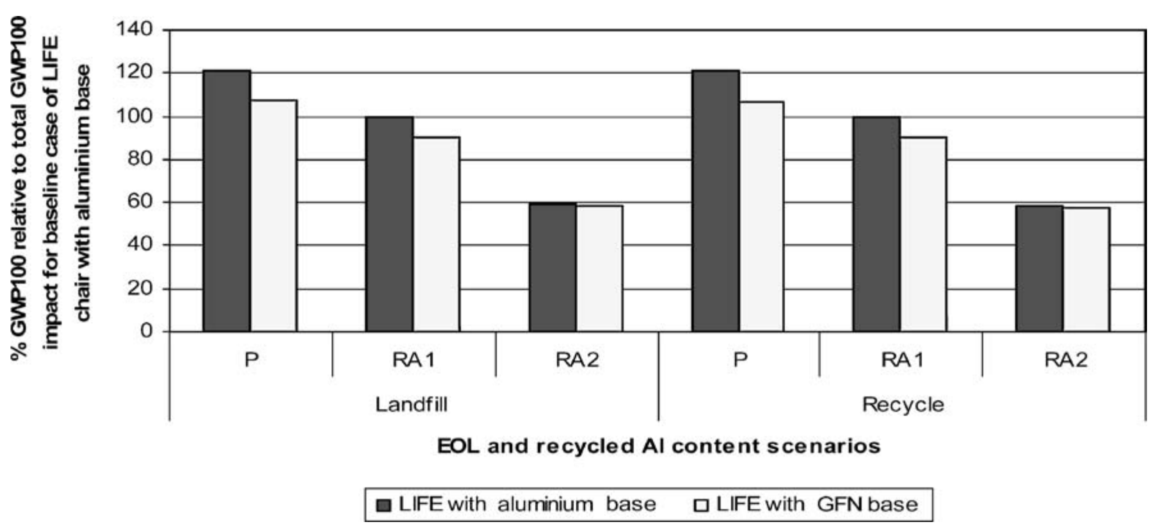

Fig. 8 Percent GWP100 results comparing the effect of consequential and attributional approaches to modelling aluminium at EOL relative to LIFE chair with aluminium base using 34% recycled aluminium content

use of the consequential approach provides an incentive for Formway to get involved in product stewardship activities, whilst use of the attributional approach does not provide any incentive for this type of activity.

Overall, these results highlight the desirability of using recycled aluminium in chair manufacture, using materials that are less energy intensive, and recycling of aluminium at EOL (at least according to the consequential approach). Additionally, the LCA study highlighted limitations pertaining to data availability specific to the New Zealand manufacturing sector. Further research into the relevance of other impact categories (eutrophication, acidification, etc.) for a New Zealand-specific case would also be beneficial in the future.

5 Summary

An environmental LCA was undertaken in order to quantify the impacts of Formway's LIFE chair models (with aluminium base and GFN base), so as to gain a better understanding of the associated life cycle impacts. The study included all life cycle stages from raw-material extraction to waste management. Data were gathered from suppliers and used to modify existing data records from the ecoinvent database. Impact assessment was carried out using the CML 2 baseline 2000 methodology available in SimaPro7. This paper presents the GWP100 results from the study. It was found that, for both chair models, the GWP100 impact was greatest at the raw-material extraction/refinement stage (which accounted for over 60% of the total GWP100 result for both chairs). Aluminium was found to be the most significant contributor to the GWP100 impact at the raw-material extraction/refinement stage. Since the aluminium base chair model has more aluminium than its GFN counterpart, the aluminium base model had a greater GWP100 impact; it had a 10% higher GWP100 impact than the GFN model. The waste-management scenarios showed that recycling at EOL is beneficial when using a system expansion (consequential) approach. Furthermore, sensitivity analysis showed that a high use of recycled aluminium in chair manufacture is beneficial. The project also assisted in compiling valuable data on Formway products and prompted investigation of the cleaner production efforts of companies in Formway's supply chain.

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Appendix 1

(1) *Raw-material extraction and refinement*. The materials required for manufacturing the LIFE chair are given in Fig. 1. The data used for raw-material extraction and refinement were taken from the ecoinvent database. The electrical energy models were modified to reflect the respective locations as shown in Table 2. Note that transport of materials from raw-material extraction and refinement to component manufacture was not considered due to insufficient data. This is because suppliers have numerous and variable sources of material supply according to market criteria such as material availability and price.

(2) *Manufacture of LIFE components*. At the component manufacture stage, suppliers use extracted and refined materials to manufacture components according to design criteria. The main processes used by Formway's suppliers are listed in Table 3. Data from suppliers were used to modify existing records in the ecoinvent database so as to determine a Formway-specific case.

(1) *Transport of components to Formway.* The transport scenario considers transportation of components from suppliers to final assembly at Formway via road and sea as given in Table 4. Where distances of less than 100 km are considered, small trucks (16 tonnes) are used for transport. For distances greater than 100 km, large trucks (32 tonnes) are used. Commercial freighters are used for all sea transport.

(2) *Assembly and packaging of LIFE*. The components are assembled using hand and power tools at Formway's Wellington plant in New Zealand. Assembling only requires electrical energy and manpower.

(3) *Transport of product to customer and to waste management*. This study considers the transport scenario where the assembled and packaged LIFE chairs are transported to a customer in Sydney, Australia. The respective transport modes and dis-

Table 3 Component manufacturing processes

Material	Process
Aluminium	Die-casting
Steel	Machined
Polypropylene	Injection moulding
Glass filled nylon	Injection moulding
Acetal	Injection moulding
Polyurethane foam	Reactive injection moulding
Back suspension fabric	Extruded polyester filament

Table 4 Transport 1: modes and distances from suppliers to Formway

Material	Location	Road (km)	Sea (km)
Aluminium	USA	17.3	10,742
	China	45.3	8,953
	New Zealand	190	–
GFN	Australia	35.3	1,490
Fabric	Germany	429.3	11,585
Steel	China	200	10,050
	New Zealand	650	–
PBT	New Zealand	190	–
Other plastics	New Zealand	190	–
	USA	578	18,761
Cables	USA	131.3	10,176

Table 5 Transport 2: modes and distances from Formway to customer

Location	Mode of transport	Distances (km)
Formway manufacturing plant to Port of Wellington	Road	15.3
Port of Wellington to Port of Sydney	Sea	1,236
Port of Sydney to Australian distribution plant	Road	17.2
Australian distribution plant to customer in city centre	Road	16.3
Customer to landfill	Road	42
Customer to recycling facilities		
Aluminium components	Road	941
Steel components	Road	1,740

tances are given in Table 5. Where distances of less than 100 km are considered, small trucks (16 tonnes) are used for transport. For distances greater than 100 km, large trucks (32 tonnes) are used, and freighters are used for sea transport.

(4) *Use phase and waste management.* No environmental exchange takes place during use of the chairs since the product does not require energy or water to function, and it was assumed that no significant repairs are made during its life. The only foreseeable need was cleaning, which includes wiping the surface to clear dust or any marks, and is expected to have negligible environmental consequences.

Appendix 2

Figure 9

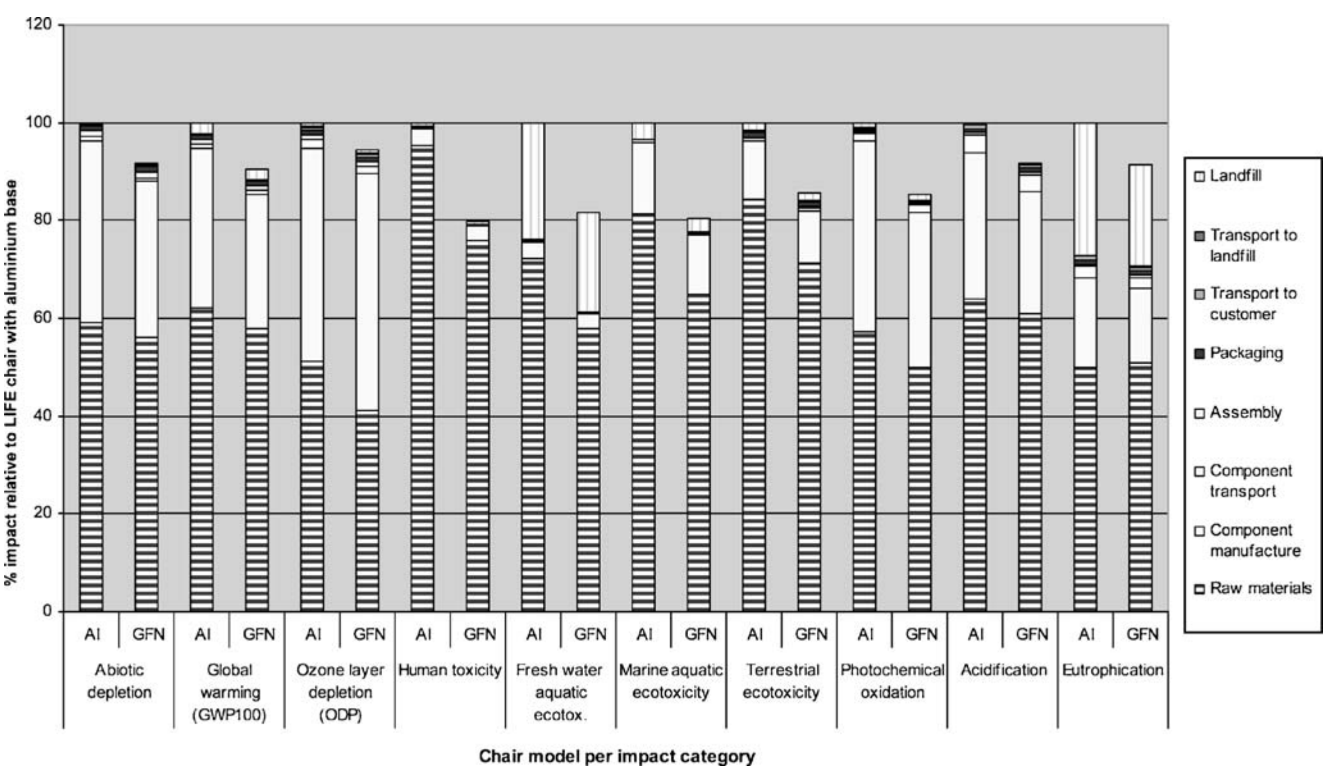

Fig. 9 Comparison of the two LIFE chair models at impact assessment

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