University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Towards Zero Waste: An Environmental Life Cycle Analysis of New Furniture vs Participation in the Furniture Reuse Program

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EXECUTIVE SUMMARY

With the steady increase of furniture consumption and increase in the sector's emission intensity, it is imperative to gain quantitative insight into the extent of these emissions and where they are rooted in the product's life cycle. Identifying the environmental and economic viability of sustainable alternatives for this sector will facilitate the decision-making shift towards less emission intensive practices in the future and help reach UBC's goal in achieving net-zero emissions by 2035. Therefore, this project aims to quantitatively identify the emission reduction potential of purchasing reused furniture compared to buying furniture new. More specifically, our assessment focuses on the unique scenario of UBC's furniture reuse program to provide UBC decision-makers and community members with context specific data regarding the potential benefits of utilizing the program.

Our assessment employs the methodology of a life cycle analysis to account for the different emission hotspots throughout the product's life cycle and make a relative comparison between different grades (low and commercial) as well as different brands (IKEA and Wayfair) of tables against the reused alternative. The representative low-grade table and commercial-grade table for IKEA and Wayfair were selected based on cost (source: Ikea and Wayfair websites). The LCA methodology provides a holistic way of assessing product emissions allowing decision making from the perspective of the system as a whole. By focusing on a ten-year span of furniture use as a functional unit, our results account for both the impact of purchasing an individual table as well as the quantity of tables purchased over the time period based on assumed life span. Our methods include the collection of primary and secondary data on table production, packaging production, and transportation to develop an inventory for each product. The inventory data was then converted into data that could be imputed into the modeling software, openLCA, alongside the database ecoinvent_38 which was used to develop the product system for each table. By applying different reuse factors to the reused table product system, we were able to evaluate different scenarios of emission accountability on the second user.

We assumed that only the commercial-grade tables (IKEA commercial-grade, and Wayfair commercial-grade) were good enough to be used for the Reuse program as those tables had long warranty and we compared the emission of buying those brand-new table versus reusing the table from the Furniture Reuse Program (IKEA reused, Wayfair reused). 'IKEA reused' refers to the IKEA commercial table diverted from landfill by the UBC reuse program, giving the table a second life instead. Similarly, 'Wayfair reused' refers to the commercial-grade Wayfair table recovered by UBC Furniture Reuse Program. The results of our analysis suggest that the lowest emitting to highest emitting tables were IKEA reused (provided by UBC reuse program), Wayfair reused (provided by UBC reuse program), IKEA commercial-grade, IKEA low-grade, Wayfair commercial-grade, and lastly Wayfair low-grade over the 10-year span. These results suggest the viability of utilizing the furniture reuse program as a means of reducing UBC's furniture emission footprint with 85-97% and 60-95% of emissions being avoided by purchasing the second-hand Wayfair (Wayfair reused) and IKEA (IKEA reused) tables respectively. Furthermore, it was determined that tables produced by IKEA brand contributed 61.89% (low cost) and 15.44% (commercial) lower in emissions when compared to their Wayfair counterparts. Assessing the lifecycle hotspots suggested that the major contributor to the low-grade IKEA table's emissions were paper production followed by steel casting whereas Wayfair's major contributors were determined as fiberboard production followed by packaging.

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LIST OF ABBREVIATIONS

CO_2 - Carbon Dioxide Emissions

GHG - GreenHouse Gas

GWP - Global Warming Potential

LCA - Life Cycle Assessment

UBC - University of British Columbia

kg CO_2e - Kilogram Carbon Dioxide equivalent

LDPE - Light Density Polyethylene

1. Introduction

1.1 Research topic

Furniture goods produce significant greenhouse gas (GHG) emissions from cradle to grave and the consumption of furniture goods is steadily increasing. This report quantifies and compares the environmental impact (kg CO2e) associated with new furniture procurement and use at UBC and the equivalent re-used furniture items from the Furniture Reuse Program at UBC. The carbon emissions of new and reused low-grade and commercial-grade furniture were quantified according to ISO 14040 and 14044 standards over a 10-year use period.

1.2 Research relevance

By providing insight into the carbon emissions associated with the life cycle of both new and reused furniture, our research may provide quantitative evidence of the carbon savings associated with purchasing and using reused furniture. This information may inform shifts in furniture procurement practices from new to reused at UBC for faculty and staff and contribute to UBC achieving net-zero emissions by 2035.

1.3 Project context

As climate change persists, phenomena including rising global temperatures, ocean acidification and increased frequency of extreme weather events are becoming increasingly concerning for both human health and ecosystems. To minimize these impacts, governments around the world have agreed on targets to reduce their harmful greenhouse gas (GHG) emissions. To reach said emission reduction targets, it will be necessary to evaluate various industries, quantify their greenhouse gas emissions and identify opportunities for GHG mitigation.

The globalized furniture market has grown significantly in the past decade in response to increasing consumption rates and is projected to increase by 5.02% annually from 2023-2028 in Canada (Statista, 2023). As furniture consumption continues to increase so will the emission intensity of the industry, therefore there is great scope for the industry to assess and mitigate carbon emissions.

Previous work in furniture life cycle assessment largely concludes that the pre-manufacturing and raw material extraction processes, followed by transportation processes contribute to the majority of environmental impacts associated with the life cycle of furniture items (Krystofik, et al., 2018, Medeiros, et al., 2017). The reuse of furniture provides a community-based solution to curb the majority of emission-intensive processes in the furniture industry by eliminating the need for new materials, extensive manufacturing, and reducing transportation.

1.4 Project purpose, goals and objectives

The purpose of this project is to understand and compare the environmental impacts associated with the life cycle of new and reused furniture at UBC to inform both UBC decision-makers and community members on the impacts of different furniture procurement practices.

The goal of this project is to quantify the environmental impacts of both new and reused furniture at UBC and encourage a shift from new to reused furniture procurement on campus.

The objective of this project is to quantitatively identify and compare the environmental impact of both low-grade and commercial-grade tables from popular retailers (IKEA and Wayfair) as well as the equivalent items if they were to be purchased from the UBC Furniture Reuse Program. This will be done per the ISO 14040 and 14044 standards over a 10-year use period.

1. Data Collection
    a. Record the type and quantity of input materials of each furniture item included in the assessment
    b. Record the mode(s) of transportation[1] and distance traveled for a furniture item to reach its use-phase
    c. End-of-life was assumed to be the landfill
2. Modeling
    a. Create a model accounting for the production of each furniture item
    b. Create a model accounting for the packaging of each furniture item
    c. Create a model accounting for the transportation of each furniture item
3. Interpretation
    a. Quantify results according to the ISO 14040 and 14044 standards over a 10-year use period
    b. Compare the environmental impact (kg CO2e) of all furniture items included in the assessment
4. Recommendations
    a. Define and describe our recommendations to UBC faculty, staff and community members regarding furniture procurement and disposal practices based on our findings.

2. Methodology and methods

2.1 Research methods

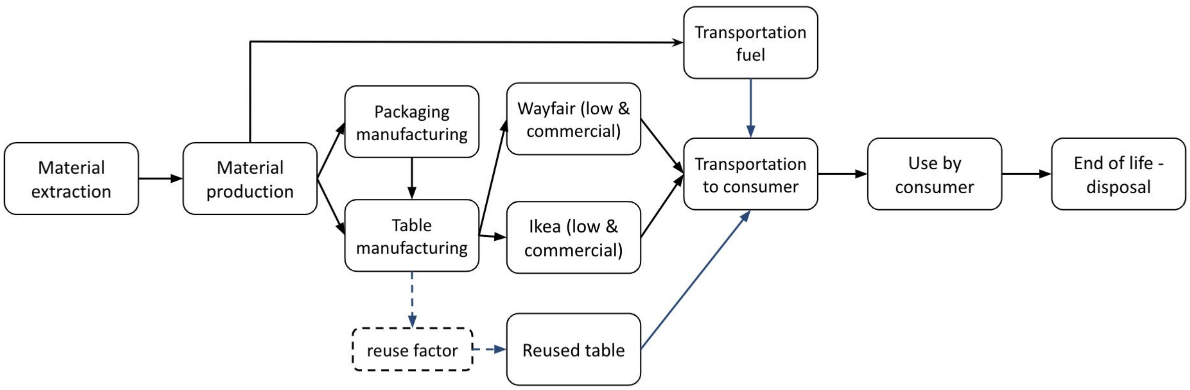
Our assessment utilizes a methodology known as the life cycle analysis which broadly looks at the environmental and/or social impacts associated with products and processes across various life cycle stages including upstream, use, and downstream phases. The inputs and outputs of various processes defined within a system boundary are represented as process flows inputted into a product system. We conducted our analysis following ISO 14040 and 14044 guidelines provided by The International Organization for Standardization. Conducting an LCA may be used as a tool to inform decision-making in regards to climate impact and sustainability of a given product or process by weighing the associated quantitative impacts.

[1] Transportation takes into account only the upstream processes (the distance travelled from a local warehouse to UBC). This assumption was made to simplify calculations for our model.

To develop our methodology, we first defined our goal and scope, as well as other parameters which allowed us to generate an organized methodology for collecting data needed to develop a model. In terms of our goal, our model aims to assess the environmental impact, quantified as global warming potential (GWP), of used furniture relative to new furniture. The scope of our model includes identifying and measuring the environmental impact of the manufacturing, upstream transportation and disposal processes. Ultimately, this assessment should allow us to identify major contributors to the environmental impact of the product's life cycle in terms of material inputs and processes. Aligning with our goal and scope, we developed a general modeling question: What is the global warming potential (GWP) for each table considering its manufacturing process, packaging, upstream transportation and end-of-life treatment? From our modeling question, a functional unit was established. The purpose of a functional unit in the context of an LCA is to provide a quantified performance of a product system for use as a reference unit. The chosen unit should be applicable to all systems or products being compared in the assessment. In the case of our modeling question, we chose a functional unit of the number of tables used within a ten year "life span". This unit allows for the different expected life spans based on product quality to be accounted for. For example, the lifespan of a low-grade table may be significantly lower than that of a high-end table. This would result in the low-grade table being purchased more often over a ten-year period which contributes to its overall footprint over the ten-year period.

As mentioned previously, an LCA quantifies the environmental impact of a product from one phase in its life to another within a defined system boundary. We performed a cradle-to-grave LCA which considers processes from raw material extraction to end of life (such as disposal or reuse) for all tables. For the reused tables, production flow is equivalent to their commercial table counterparts as they are assumed to be the same table. However, a reuse factor is added to account for the percentage of production emissions associated with the second user, with a reuse factor ranging from 0-1. We created two scenarios and adjusted accountability using a reuse factor of 0 and 0.5 suggesting that the second user accounts for 0% and 50% of the table's production emissions respectively. An emission factor of zero accounts for a scenario where none of the upstream emissions from the purchase of the new table, by the original user, falls on the purchaser (second user) of the reused table from the furniture reuse program. This is assuming the fact that the reused table was already there and no new resources or refurbishment was done on it, so only the emission due to transportation is the main factor. In the second scenario, an emission factor of 0.5 is reflective of the lifespan emissions from the table in that it suggests the second user purchasing from the furniture reuse program is responsible for 50% of the upstream emissions. The rationale behind this assumption is that the original user is not getting the full use and instead only half the use - relative to the table's full lifespan. Moreover, there is a possibility that the original user could have disposed of the table in a landfill. However, the user consciously decided to opt for the reuse program to donate and the second user can use the table for the other half of the life span. Therefore, the second user is partly accountable for the table's emissions proportional to the point at which the table is purchased from the program during its lifespan, in this scenario being half way. The implications of this from an emissions perspective would be that the reused table, from IKEA for example, with an emission factor 0.5 (50%) would have half the emission impact from the new IKEA table's material extraction, material production, packaging manufacturing, table manufacturing, and transportation from the warehouse to the original user as well as the full emission impact from the transportation of the reused table from the furniture reuse program to the second user. The phases within this system boundary that are applicable to the reused table are partially the phases up to and including the upstream emissions to the point of "use by consumer" and the transportation of the table from the furniture reuse program to the second user. Transportation from the production facility to various shipping checkpoints - and eventually the Vancouver warehouses - were omitted from the system boundary due to a lack of available primary data and insufficient information to form meaningful assumptions. This will also add to the GHG emissions for the production of new tables, so the reported GHG emissions in this study are the low-end estimates. Therefore, the transportation route used in the analysis for the new tables only accounts for the route taken from the nearest Vancouver warehouse to the original user at the UBC Vancouver campus. Additionally, transportation of the material inputs for the tables from the point of material extraction to the manufacturing plant and the subsequent products from the manufacturing plant to the table production facilities were omitted - once again due to the lack of available primary data. The system boundary is demonstrated in Figure 1. Lastly, before starting the data collection, we conducted an inventory analysis to identify what data needed to be collected. We needed primary data for table dimensions, materials, and transportation as well as secondary data for assumptions, transportation, data conversion, and any materials that were not specified within our primary data. The three tables being studied include both a low and commercial-grade table for IKEA and Wayfair, as well as a reused table from the furniture reuse program for both companies.

Figure 1: System Boundary Selected For The Table LCA



2.2.1 PRIMARY DATA COLLECTION RESEARCH METHODS

As previously stated, our LCA model has three interconnected components: the table, packaging, and transportation[2]. Primary data collection included noting the table components, transportation mode and distance for the new and reused tables. Our sample size for new tables consisted of four tables of two different grades (low-grade and commercial-grade), from two different companies (Ikea and Wayfair) to understand the role of quality in the final environmental impact. Although the furniture reuse program hosts a variety of furniture products that could have been the focus of the analysis, we selected a table as our product of interest as its dimensions and materials are relatively simple to model as compared to other furniture products. Additionally, tables across different manufacturers and brands are often similar in their size and composition allowing for a more consistent comparison between similar grade tables produced by different companies.

Regarding the new tables from Wayfair and IKEA, the dimensions and majority of materials of each table were recorded directly from the company websites on the product's online page. Some materials however, were not disclosed by primary online sources and so were instead assumed - which will be discussed in the following section. Using this primary data, we were able to calculate the mass or area of each component which would be later inputted into our product system. Regarding transportation, primary data respecting the mode of transportation and distance for the re-used tables was provided directly from the furniture reuse program. As for the new tables, each company's local warehouse near Vancouver was researched and located online. The primary data was organized into spreadsheets delineating tables based on grade and brand.

[2] Transportation considers the distance travelled and mode of transportation from a local warehouse to UBC. For the reused tables, this distance was assumed to be 4 km (2 km for delivery to the warehouse and 2 km for delivery to its final destination).

2.2.2 Secondary data collection research methods

Once the primary data was collected, secondary data as well as data regarding any assumptions were collected to fill the gaps in our inventory. To calculate the amount of each material used collected as primary data, information was either found online or assumed based on available information. For example, the density of a material was collected as secondary data to convert primary data (cubic meters of wood) into a mass of product which could be inputted into our model (kilograms of wood). As for dimensions, the detailed data that was not published by the companies were given assumptions that were kept consistent for all tables. An example of this would be the material of leg pads and its dimensions as this was not specified on the Wayfair website for either grade of table. The final spreadsheet included the product (brand and grade of table), its components (table top, table legs, steel reinforcement, etc.), the material of each component, the dimensions of components available from primary sources, the assumptions for conversions and the assumption's source, and the final amount of each component and its materials used. As for transportation, the spreadsheet included the location of the nearest warehouse, the route to the UBC Vancouver campus (kilometers traveled), and the mode of transportation. This information provided a sufficient amount of data for our openLCA model. Ultimately, by adding this data to the spreadsheet and compiling an inventory of both primary and secondary data, each table, packaging, and transportation was converted into a ready to model form in units that could be inputted directly into openLCA.

Additionally, there were various assumptions made while creating the model in which secondary data needed to be collected and applied. For the transportation process from the Vancouver Warehouse to the UBC Vancouver campus, it was assumed that the tables were located in the company's warehouse closest to Vancouver before being transported to the UBC Vancouver campus. As for table lifespan, which relates back to our ability to apply our model to a functional unit, the lifespan of each table was assumed with reference to their warranty time. The lifespan of the same table grade is also assumed to be uniform, therefore, all low-cost tables have the same life span and all high-cost tables have the same lifespan. The assumed lifespan of each table is shown in Table 1. Ultimately, secondary data served the purpose of converting and applying assumptions to primary data so that each material could be inputted into the model in the relevant units of distance, mass, or area.

Table 1: Life Span of table from different sources and the reused tables

Table retailer	**Table grade**	**Life span (years)**
Wayfair	Low-grade	3-4
Wayfair	Commercial-grade	10
Wayfair	Reused	10

IKEA	Low-grade	2-3
IKEA	Commercial-grade	10
IKEA	Reused	10

2.2.3 Model creation and revision

Our model was constructed in openLCA, A professional software used for calculating the life cycle impact of a product. This software is easily accessible with various databases available online for download. Specifically, our methodology utilizes the database ecoinvent_38 as a main source of data modeled in openLCA. Model creation for each table involves four major parts: table production, packaging, end-of-life treatment, and transportation.

Table production is modeled in openLCA with the input as the materials used in manufacturing - such as fiberboard, steel, plastic, and coating materials - and the output as the table. Each of the four new tables (Wayfair low-grade, Wayfair commercial-grade, IKEA low-grade, and IKEA commercial-grade) are modeled separately since the tables have different material inputs. As previously stated, the production of the reused table is the same as the respective commercial tables, since they are assumed to be the same tables with a reuse factor applied to adjust for the accountability of emissions.

Packaging, similar to table production, is modeled by inputting packaging materials such as the cardboard box, plastic film, and bubble wrap. The output is the packaging. Packing for each of the four new tables are also modeled separately, and the packing output is added into models of tables as an input. Reused tables are assumed to have no packaging.

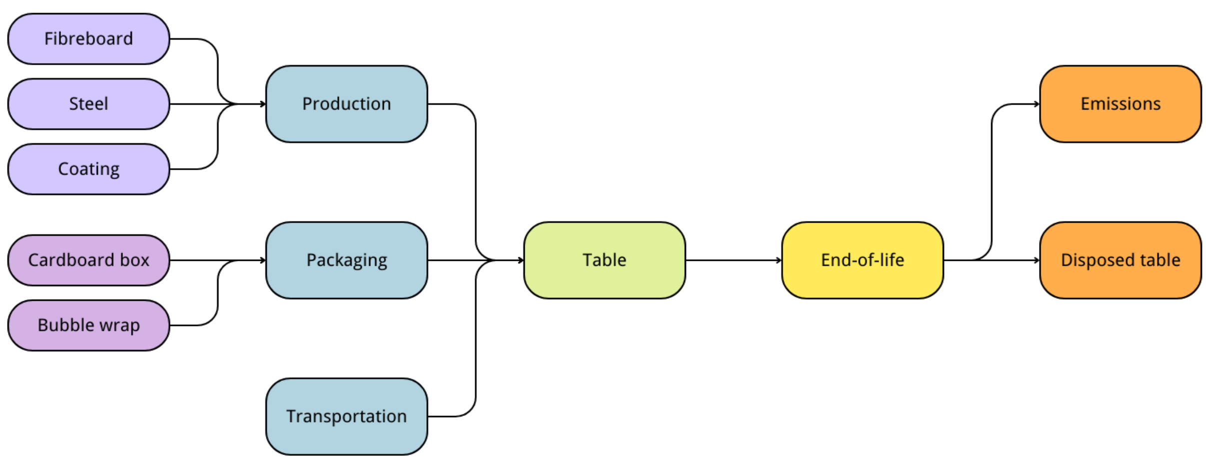
End-of-life treatment is modeled in openLCA, but the emissions from tables in landfill are calculated based on emission factors provided by USEPA (2021). Total emission from each table is calculated by adding up emissions from each material in one table. The emission of each material is calculated by timing emission factor to weight of each material. In the model, disposal processes for each table are created, with the disposed table being the input, and emissions being the output. Disposal emissions for reused tables have a reuse factor applied to account for the reduced number of disposals by reusing a table.

Transportation is added to the model as an input. The transportation distance is determined by calculating the distance between UBC and the nearest warehouse of the corresponding company. The transported weight is assumed to be the weight of each table. Transportation distance for reused tables is assumed to be 4 km on average. The transportation in the disposal process is already accounted for in the emission factors, so additional transportation is not added to the disposal process.

Linkage between model elements are shown in Figure 2. This flowchart shows how each part of the model is connected together. Note that due to limited data availability and research capacity, the "transportation" flow only includes the furniture's transportation from local warehouses to UBC. After linking all the elements, the final model represents the full life cycle of a table within the scope of our study.

Finally, the processes for different tables are compared to obtain results on the global warming potential of each table. The number of tables used in our time span of 10 years is determined based on the expected life span of each table. Wayfair low-grade table has an expected life span of 3.33 years, which means 3 tables are used in 10 years. Both commercial tables and reused tables are expected to last 10 years, so 1 of each is used in 10 years. Similarly for IKEA, three low-grade tables were required in a span of 10 years and 1 for both commercial as well as reused tables in a 10 years period.

Figure 2: Model structure for table[3]



3. Results

3.1 Wayfair

3.1.1 Open LCA Model Graph

Wayfair low-grade and commercial-grade tables differ primarily in their overall weight. The main materials used are almost identical, but the commercial-grade table has more steel for structuring and thus has a longer lifespan. The inputs into the Wayfair low-grade and commercial-grade tables are shown in Figure 3. As shown in the figures, the low-grade table contains 3.67 kg of steel, which makes up the frame and legs of the table. The commercial-grade table

[3] Transportation assumption: Due to limited data availability and research capacity we only included the transportation emissions incurred from the distance traveled between a local warehouse and the consumer (UBC). Transportation emissions throughout the rest of the product life cycle were not accounted for.

contains 7.36 kg of steel, which is double the amount of low-grade table, resulting in a better support of structure and longer lifespan.

Figure 3: List of input flows for the Wayfair low-grade and commercial-grade table

Inputs/Outputs: Wayfair Low

Inputs

Flow	Amount	Unit
acrylic dispersion, without water, in 65% solution state	0.09688	kg
casting, steel, lost-wax	0.06000	kg
injection moulding	0.08000	kg
medium density fibreboard	0.02436	m3
polypropylene, granulate	0.08000	kg
powder coat, steel	1.50200	m2
section bar rolling, steel	3.67414	kg
transport, freight, light commercial vehicle	DWL*WWL	kg*km
Wayfair Low Packaging	1.00000	Item(s)

Inputs/Outputs: Wayfair Commercial

Inputs

Flow	Amount	Unit
acrylic dispersion, without water, in 65% solution state	0.12931	kg
casting, steel, lost-wax	0.09200	kg
injection moulding	0.08000	kg
medium density fibreboard	0.02439	m3
polypropylene, granulate	0.08000	kg
powder coat, steel	3.00000	m2
section bar rolling, steel	7.36000	kg
transport, freight, light commercial vehicle	DWC*WWC	kg*km
Wayfair Comm Packaging	1.00000	Item(s)

The resulting models are shown in Figures 4 and 5. As explained in the methodology, production materials, packaging, and transportation flow in, and disposal is the outflow. The reused table is a Wayfair commercial table resold by the Furniture Reuse Program. For the reused table, no packaging is included. Models for Wayfair commercial-grade, Wayfair low-grade, and Wayfair reused table are calculated and compared by openLCA.

Figure 4: Model graph for Wayfair Commercial table which includes the Material processing, transportation as well as landfill emissions

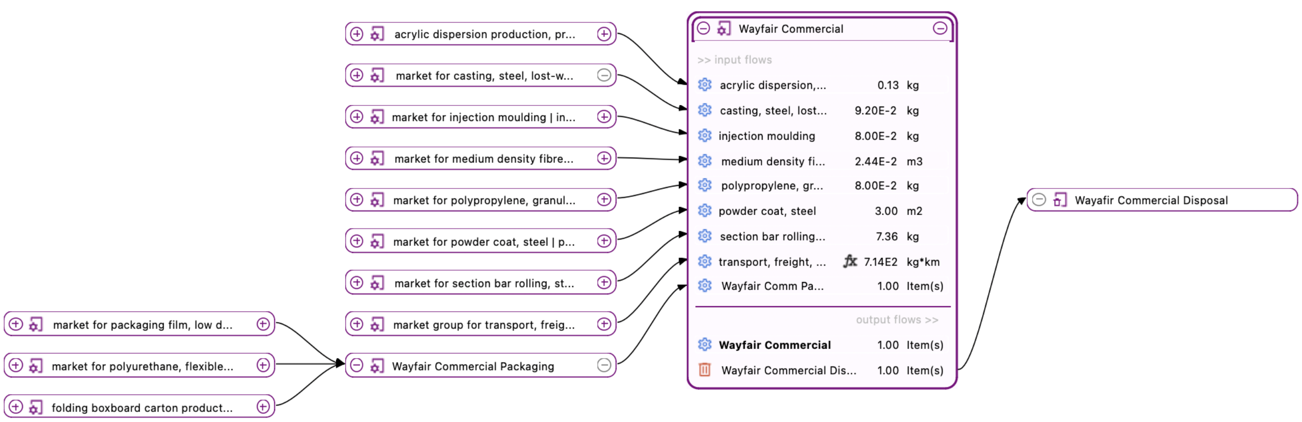
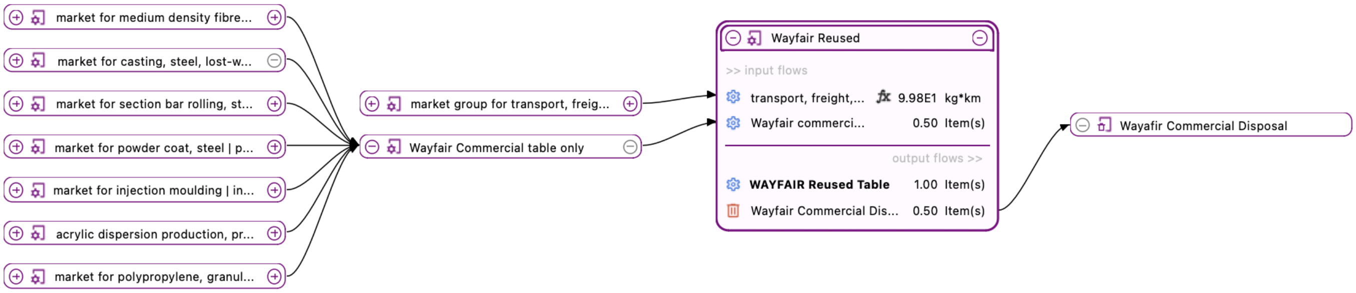


Figure 5: Model graph for Wayfair reused table which includes the Material processing, transportation as well as landfill emissions



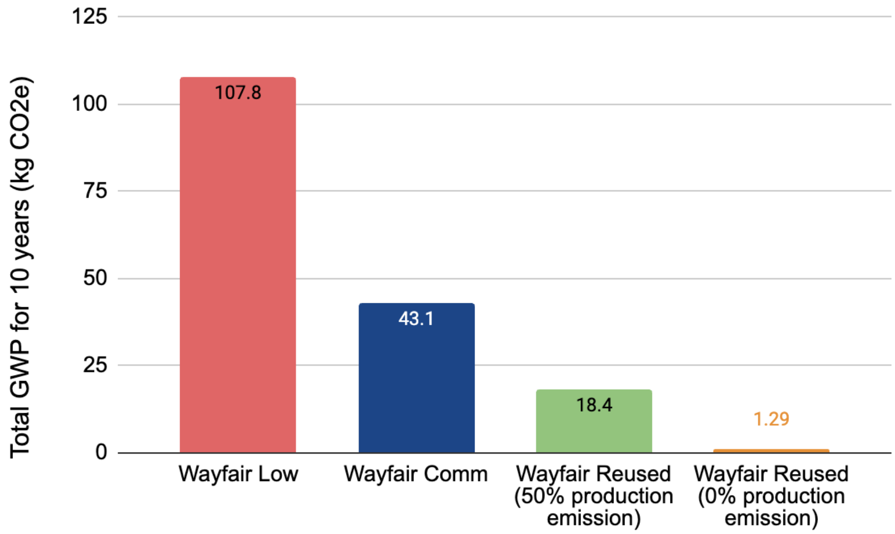
3.1.2 Global warming potential of Wayfair tables

The results of calculation are shown in Table 2. The same results are visualized in Figure 6. 'Wayfair reused' refers to the table rescued by the UBC Furniture Reuse Program. The '50% of production-related emissions' indicates the production emissions of the reused table is assumed to be 50% of the original table, which is the Wayfair commercial table. The '0% of production-related emissions' indicates none of the original production emissions are accounted for by the reuser. As shown in the bar chart, Wayfair commercial-grade has a GWP more than 50% lower than Wayfair low-grade tables, while the Wayfair reused table is showing another reduction of over 50% for the criteria 1, where we assumed that the second user is responsible for the 50% of production emission. Wayfair low-grade table produces a highest GWP of 107.821 kg CO2 eq in 10 years, while Wayfair reused table produces a lowest of 18.4126 kg CO2 eq in 10 years (second user responsible for 50% emission) and 1.29 kg CO2 eq in 10 years (assuming 0% of production-related emissions). In comparison, Wayfair reused tables achieved a GWP reduction of over 80-97%.

Table 2: Global warming potential of Wayfair tables (Low, Commercial and Reused)

	Global Warming Potential per 10 year period (kg CO2 eq)
Wayfair Low-grade	107.8
Wayfair Commercial	43.1
Wayfair Reused provided by UBC Reuse program (assuming 50% of production-related emissions)	18.4
Wayfair Reused provided by UBC Reuse program (assuming 0% of production-related emissions)	1.29

Figure 6: Global warming potential of Wayfair tables over 10 years



3.1.3 Top contributors (activities) to GWP - Wayfair table

To see the composition of GWP producers during the lifespan of the tables, the top contributors to GWP for Wayfair commercial-grade table and low-grade table are shown in Figures 7 and 8 as examples.

For Wayfair's commercial and low-grade tables, the top 5 contributors are:

1) Disposal (Landfill)
2) Ammonia production
3) Polyol production
4) Heat production from coal
5) Heat production from natural gas

Figure 7: Top contributors (activities) to global warming potential in the Wayfair commercial-grade table

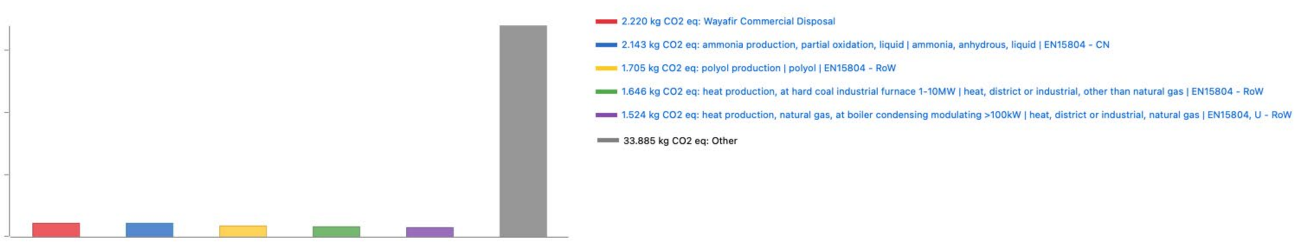
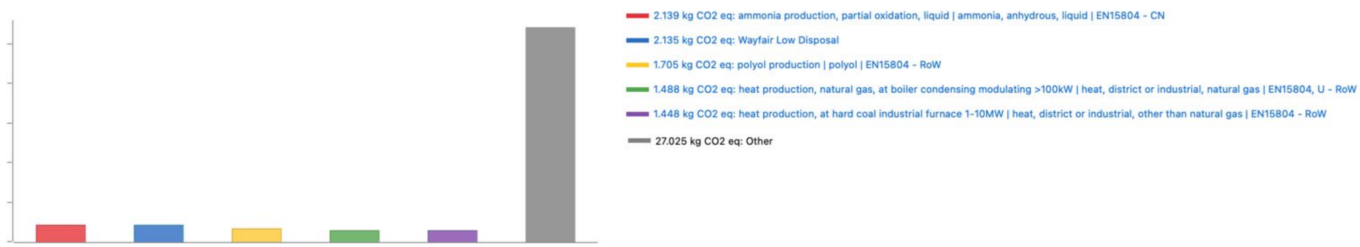


Figure 8: Top contributors (activities) to global warming potential in the Wayfair low-grade table



As shown in Figures 7 and 8, the GWP of "others" are both significantly the highest for Wayfair commercial-grade and low-grade table. This is due to the complex nature of the tables as a very large number of items are present in the components of a table which contribute to their GWP. For example, under the GWP of fiberboard used to make the tables, hundreds of items are considered, including every ingredient of the fiberboard, all forms of energy used in every step of production, and the transportation of each different ingredient.

3.1.4 Top contributors (process) to GWP – Wayfair table

When looking at the process contribution to GWP, the Wayfair low-grade and commercial-grade tables major process contributors were as follows (As shown in Figure 9 and Figure 10).

1) Fiberboard production
2) Packaging - Cardboard and LDPE
3) Steel powder coating
4) Landfill - Transportation and biogenic decay
5) Steel casting

The breakdown of the total CO_2e is also shown using Sankey diagrams in Appendix C and Appendix D.

Figure 9: Top process contributors to Wayfair low-grade table global warming potential

Contribution	Process	Required amount	Total result [kg CO2 eq]	Direct contribution [kg CO2
100.00%	Wayfair Low	1.00000 Item(s)	35.94045	
53.63%	market for medium density fibreboard | medium density fibreboard | EN1	0.02436 m3	19.27646	
14.87%	Wayfair Low Packaging	1.00000 Item(s)	5.34408	
13.91%	market for powder coat, steel | powder coat, steel | EN15804 - GLO	1.50200 m2	5.00059	
05.94%	Wayfair Low Disposal	1.00000 Item(s)	2.13517	2.13517
05.45%	market for casting, steel, lost-wax | casting, steel, lost-wax | EN15804 -	0.06000 kg	1.95800	
02.85%	market group for transport, freight, light commercial vehicle | transport,	0.55135 t*km	1.02298	
01.79%	market for section bar rolling, steel | section bar rolling, steel | EN15804	3.67414 kg	0.64413	
00.79%	acrylic dispersion production, product in 65% solution state | acrylic dis	0.09688 kg	0.28557	
00.49%	market for polypropylene, granulate | polypropylene, granulate | EN1580	0.08000 kg	0.17541	
00.27%	market for injection moulding | injection moulding | EN15804 - GLO	0.08000 kg	0.09805	

Figure 10: Top process contributors to Wayfair commercial-grade table global warming potential

Contribution	Process	Required amount	Total result [kg CO2 eq]	Direct contribution [kg CO2
100.00%	Wayfair Commercial	1.00000 Item(s)	43.12282	
44.76%	market for medium density fibreboard | medium density fibreboard | EN1	0.02439 m3	19.30028	
23.16%	market for powder coat, steel | powder coat, steel | EN15804 - GLO	3.00000 m2	9.98786	
12.39%	Wayfair Commercial Packaging	1.00000 Item(s)	5.34408	
06.96%	market for casting, steel, lost-wax | casting, steel, lost-wax | EN15804 -	0.09200 kg	3.00226	
05.15%	Wayafir Commercial Disposal	1.00000 Item(s)	2.21956	2.21956
03.07%	market group for transport, freight, light commercial vehicle | transport,	0.71350 t*km	1.32384	
02.99%	market for section bar rolling, steel | section bar rolling, steel | EN15804	7.36000 kg	1.29031	
00.88%	acrylic dispersion production, product in 65% solution state | acrylic dis	0.12931 kg	0.38117	
00.41%	market for polypropylene, granulate | polypropylene, granulate | EN1580	0.08000 kg	0.17541	
00.23%	market for injection moulding | injection moulding | EN15804 - GLO	0.08000 kg	0.09805	

3.2 IKEA

3.2.1 OPEN LCA INPUT FLOWS AND MODEL GRAPH

The main difference between the IKEA low-grade and commercial-grade table was the weight of the overall table as well as the quality of material used. For instance, the quantity of metal component required for IKEA low-grade table was around 3.4 kg which is significantly less compared to the IKEA commercial-grade (32.15 kg). The list of all flows has been shown in Figure 11. This will provide insight regarding the type and amount of materials that go into producing an IKEA table.

Figure 11: List of input flows for the IKEA low-grade and commercial-grade table

Inputs/Outputs: IKEA Commercial

Inputs

Flow	Amount	Unit
IKEA Comm Packaging	1.00000	Item(s)
injection moulding	0.43600	kg
melamine	0.25216	kg
particleboard, uncoated	0.02438	m3
polypropylene, granulate	0.43600	kg
polyvinylchloride, bulk polymerised	0.34138	kg
powder coat, aluminium sheet	0.80680	m2
powder coat, steel	0.80680	m2
section bar extrusion, aluminium	8.00000	kg
section bar rolling, steel	8.00000	kg
textile, nonwoven polyester	0.20000	kg
transport, freight, light commercial vehicle	D_IC*W_IC	kg*km

Inputs/Outputs: IKEA LOW

Inputs

Flow	Category	Amount	Unit
acrylic dispersion, without v	202:Manufacture of other chem	0.09190	kg
casting, steel, lost-wax	243:Casting of metals/2431:Ca	0.07000	kg
IKEA Packaging	BEST 402 SEEDS	1.00000	Item(s)
injection moulding	222:Manufacture of plastics pr	0.10000	kg
paper, woodcontaining, ligh	170:Manufacture of paper and p	1.14400	kg
particleboard, uncoated	162:Manufacture of products o	0.00449	m3
plywood	162:Manufacture of products o	0.00182	m3
polypropylene, granulate	201:Manufacture of basic chem	0.10000	kg
powder coat, steel	259:Manufacture of other fabri	0.35168	m2
section bar rolling, steel	241:Manufacture of basic iron a	3.48000	kg
transport, freight, light com	492:Other land transport/4923	D*Wt	kg*km

Once the input flow and output flows were added to the LCA model, we got the model graphs shown in Figure 12 and Figure 13. These figures represent the production materials, packaging and transportation in-flow as well as the disposal out-flow. Models for the IKEA commercial-grade, IKEA low-grade, and IKEA reused table are calculated and compared by openLCA.

Figure 12: Model graph for IKEA Commercial table which includes the Material processing, transportation as well as landfill emissions

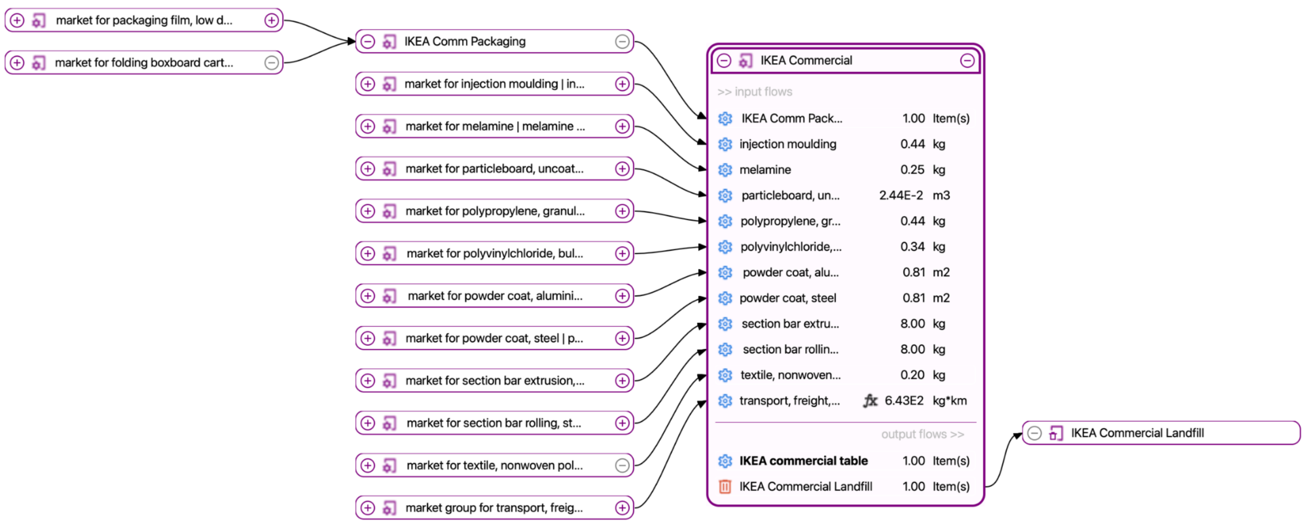
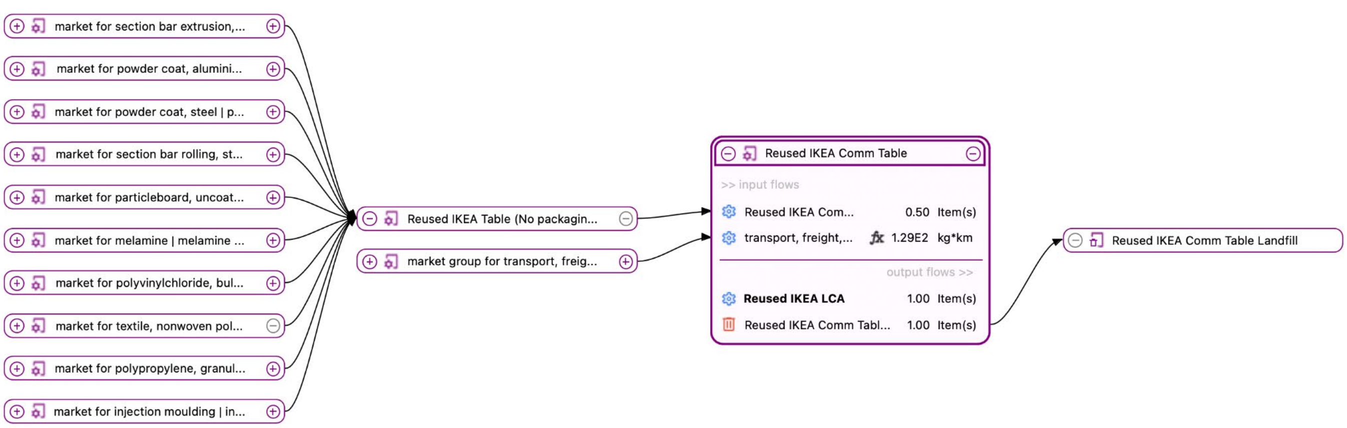


Figure 13: Model graph for IKEA reused table which includes the material processing, transportation within UBC and end of life-landfill emissions



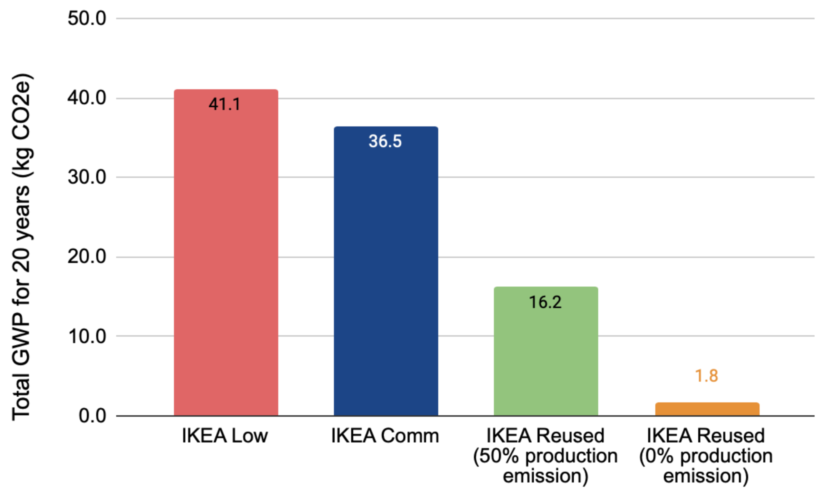
3.2.2 Global warming potential of IKEA tables

The results of calculation are shown in Table 3. The same results are visualized in Figure 14. As shown in the bar chart, IKEA commercial-grade has a GWP over 10% lower than IKEA low-grade tables as a lower number of tables are used for a 10-year period, indicating landfill emissions are also reduced. The IKEA reused table are found to have a GWP reduction of over 50-95% compared to the IKEA commercial-grade table. The IKEA low-grade table produces the highest GWP at 41.089 kg CO2 eq in 10 years, while an IKEA reused table produces a lowest of 16.226 kg CO2 eq (assuming 50% of production-related emissions) and 1.76 kg CO2 eq (assuming 0% production-related emissions) in 10 years. Therefore, relative to the IKEA low-grade table, the IKEA reused table achieved a GWP reduction of over 50%.

Table 3: Global warming potential of IKEA tables (Low, Commercial and Reused)

	Global Warming Potential (kg CO2 eq)
IKEA Low-grade	41.1
IKEA Commercial	36.5
IKEA Reused provided by UBC Reuse program (assuming 50% of production-related emissions)	16.2
IKEA Reused (assuming 0% production-related emissions)	1.766

Figure 14: Global warming potential of IKEA tables over 10 years



3.2.3 Top contributors (activities) to GWP – IKEA table

The major GWP contributors identified by our LCA for IKEA low and commercial-grade tables derived from the following activities, shown in Figure 15 and Figure 16.

1) Direct CO2 emission into the air from landfill
2) Heat Production by coal furnace
3) Coal extraction process
4) Ammonia production for making particle board
5) Heat generation to run furnace via natural gas burning

In the case of the IKEA commercial-grade table, the GWP due to ammonia production was greater than the IKEA low-grade table because the tabletop is completely composed of particle board, which is not the case with low-grade table (70% is filled with paper-based honeycomb support).

Figure 15: Top activity contributors to IKEA low-grade table GWP

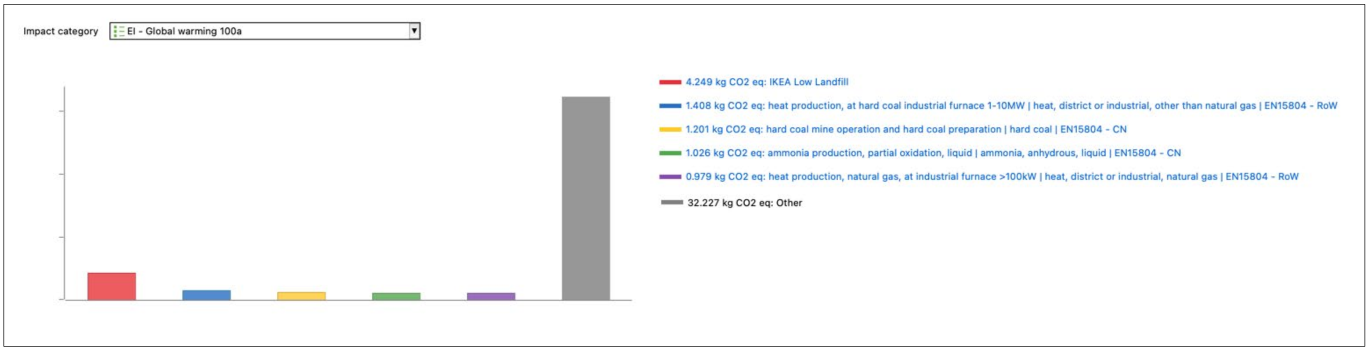
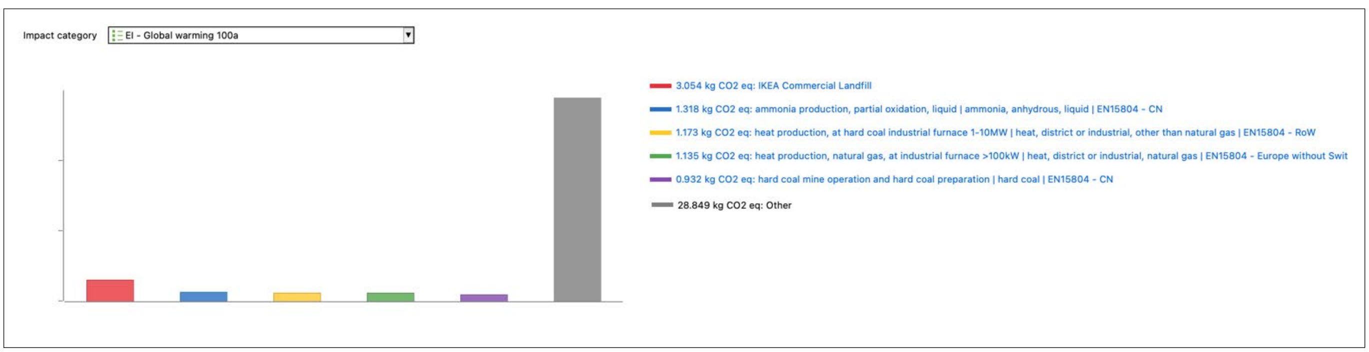


Figure 16: Top activity contributors to IKEA commercial-grade table GWP



3.2.4 Top contributors (process) to GWP – IKEA table

If we look at the process's GWP, it was observed that for the IKEA low-grade major process contributors were as follows (As shown in Figure 17 and Figure 18). The breakdown of the total CO_2e is also shown using Sankey diagram in Appendix A and Appendix B.

1. Paper production
2. Steel casting
3. Particle board
4. Packaging - Cardboard and LDPE
5. Landfill - Transportation and biogenic decay

Similarly, for the IKEA commercial-grade table, it was observed that the major process contributors to GWP were

1) Particle board production process

2) Aluminum bar extrusion
3) Packaging
4) Landfill
5) Powder coating for metal

Figure 17: Top process contributors to IKEA low-grade table GWP

Contribution	Process	Required amount	Total result [kg CO2 eq]	Direct contribution [kg CO2 eq]
100.00%	IKEA LOW	3.00000 Item(s)	41.08890	
16.69%	market for paper, woodcontaining, lightweight coated | paper, woodcontaining, lightweight coated	3.43200 kg	6.85957	
16.68%	market for casting, steel, lost-wax | casting, steel, lost-wax | EN15804 - GLO	0.21000 kg	6.85299	
12.99%	particleboard production, uncoated, average glue mix | particleboard, uncoated | EN15804 - RoW	0.01346 m3	5.33840	0.02000
12.64%	IKEA Low Packaging	3.00000 Item(s)	5.19238	
10.34%	IKEA Low Landfill	3.00000 Item(s)	4.24896	4.24896
09.79%	plywood production | plywood | EN15804 - RoW	0.00546 m3	4.02407	0.04368
08.55%	market for powder coat, steel | powder coat, steel | EN15804 - GLO	1.05504 m2	3.51253	
04.45%	market for section bar rolling, steel | section bar rolling, steel | EN15804 - GLO	10.44000 kg	1.83028	
03.39%	market group for transport, freight, light commercial vehicle | transport, freight, light commercial v	0.75000 t*km	1.39156	
01.98%	acrylic dispersion production, product in 65% solution state | acrylic dispersion, without water, in (	0.27570 kg	0.81267	
01.60%	market for polypropylene, granulate | polypropylene, granulate | EN15804 - GLO	0.30000 kg	0.65779	
00.89%	market for injection moulding | injection moulding | EN15804 - GLO	0.30000 kg	0.36769	

Figure 18: Top contributors to IKEA commercial-grade table GWP

Contribution	Process	Required amount	Total result [kg CO2 eq]	Direct contribution [kg CO2 eq]
100.00%	IKEA Commercial	1.00000 Item(s)	36.46095	
28.26%	market for particleboard, uncoated | particleboard, uncoated | EN15804 - RoW	0.02438 m3	10.30461	
19.46%	market for section bar extrusion, aluminium | section bar extrusion, aluminium | EN15804 - GLO	8.00000 kg	7.09473	
09.03%	IKEA Comm Packaging	1.00000 Item(s)	3.29367	
08.38%	IKEA Commercial Landfill	1.00000 Item(s)	3.05380	3.05380
07.37%	market for powder coat, steel | powder coat, steel | EN15804 - GLO	0.80680 m2	2.68607	
06.69%	market for powder coat, aluminium sheet | powder coat, aluminium sheet | EN15804, U - GLO	0.80680 m2	2.43933	
04.39%	market for melamine | melamine | EN15804 - GLO	0.25216 kg	1.59884	
03.85%	market for section bar rolling, steel | section bar rolling, steel | EN15804 - GLO	8.00000 kg	1.40251	
03.27%	market group for transport, freight, light commercial vehicle | transport, freight, light commercial vehicle	0.64300 t*km	1.19303	
02.88%	market for textile, nonwoven polyester | textile, nonwoven polyester | EN15804 - GLO	0.20000 kg	1.05052	
02.62%	market for polypropylene, granulate | polypropylene, granulate | EN15804 - GLO	0.43600 kg	0.95599	
02.34%	market for polyvinylchloride, bulk polymerised | polyvinylchloride, bulk polymerised | EN15804 - GLO	0.34138 kg	0.85346	
01.47%	market for injection moulding | injection moulding | EN15804 - GLO	0.43600 kg	0.53438	

4. Discussion

An LCA was conducted and analyzed to yield the environmental impact, quantified as GWP, of 6 different tables sourced from 2 companies (Wayfair and IKEA - Commercial and Low-grade) and we used 'IKEA reused' and 'Wayfair reused' as a representative of the furniture reuse program. This analysis takes into consideration various life cycle stages including upstream, use, and downstream phases in the production of the tables. The compiled data from our LCA identified the most to least sustainable table options to be the IKEA reused, Wayfair reused, IKEA commercial-grade, IKEA low-grade, Wayfair-commercial-grade, and lastly Wayfair low-grade when considering the life-span of each table to be 10 years.

The reused tables of both brands yielded significantly lower global warming potential values relative to their new counterparts. The reused Wayfair table, for instance, avoided 57-97% of the carbon emissions relative to its new commercial-grade equivalent, while the reused commercial-grade IKEA table avoids 56-95%. The reason for the broad range is because of our assumptions about the production emission we made for the reused table (Case 1: second user responsible for 50% production emission; case 2: No production emission from reused table). These reductions in environmental impact are reflective of the avoidance of new raw material extraction, manufacturing processes, packaging and some transportation associated with a reused table, relative to a new table. Rather than being transported to the landfill, the reused tables are sold in a ready-to-use form, allowing for the extension of its lifespan and maximization of the resources utilized for the table. It is known to the general public that actions that can help the environment include the 3Rs, namely reduce, reuse, and recycle. It should be taken into consideration that high-quality items have the potential to be reused.

Based on the data presented, it is also recognized that the production of tables from IKEA is more environmentally sustainable than those manufactured by Wayfair. In both scenarios the IKEA tables, low and commercial-grade, had 61.89% and 15.44% lower emissions respectively when compared to those of Wayfair tables. With this information in mind, when sourcing a new table, IKEA would be a better brand choice for environmentally conscious consumers.

While reused tables are associated with reducing the environmental impact of furniture consumption, they also reap economic benefits. Calculations for the overall monetary input for the purchase and disposal of the tables over a 10-year lifespan conclude that the reused tables from the UBC Furniture Reuse Program have the best value. For instance, the reused IKEA commercial-grade table is priced 99 CAD less than its closest equivalent IKEA commercial-grade table. Furthermore, if the carbon emissions avoided from utilizing the reused table was instead offset in the carbon market at current market price, the cost of the low and commercial-grade tables would increase drastically.

A handful of limitations are present in the study which should be accounted for. One of the limitations present includes the limited access to required data. As a result of this, educated assumptions were made which may slightly impact the results. These assumptions include making inferences on the amount of material used for each product, the pathway of transportation taken from the warehouses to the consumer, and its proper disposal at the end of its lifetime. Additionally, the environmental analysis of the study is primarily focused on GWP, overlooking other aspects such as eutrophication, acidification, ozone impact and more.

5. Recommendations

5.1 Recommendations for Action

This study supports that the UBC Furniture Reuse Program provides both environmental and financial benefits to the UBC community by collecting and re-selling reused furniture items. Due to the environmental and financial benefits, it is recommended that resources be provided to allow for the growth and expansion of the program. Reducing carbon emissions from furniture is in-line with UBC goals in the Climate Action Plan 2030 and the Zero Waste Action Plan: Towards a Circular Economy 2030.

Moreover, given its strength, our recommendations for the program is to develop strategies to render the organization more exposure to the public and possibly other institutions that would be interested in purchasing their re-used furniture items.

5.2 Recommendations for Future Research

Several areas for improvement and expansion of our report have been identified. Firstly, expanding the scope of both furniture brands and furniture items are crucial, as IKEA and Wayfair are not the sole retailers of furniture and there are many different mass-consumed furniture items that have variable environmental impacts. By considering other furniture providers (For example Staples) and furniture products, the data collected will be more representative of a realistic scenario in which there are many furniture items, reused and new, that vary in their environmental impact. This expanded insight may be beneficial in understanding a more accurate average environmental impact of new to reused furniture items and also in comparing the environmental sustainability of different furniture brands and products.

Additionally, it is essential to explore various potential scenarios. While our current study focuses on the tables with a lifespan of 10 years, realistically the use of these products may vary. Tables that are located in a highly trafficked area might need to be replaced more often compared to those with less use. Lastly, this report only covers downstream emissions along with upstream emissions from manufacturing and raw material extraction. Going forward, a thorough cradle to grave analysis can be performed including the transportation of raw materials to the manufacturing sites, the transportation to the production facilities and warehouses. This additional data can help provide a more accurate perspective on the environmental impacts of the tables from IKEA and Wayfair given their different quality grade.

6. Conclusion

This report focuses on identifying the amount of carbon emission made throughout the life cycle of a low-grade, commercial-grade, and reused table sourced from IKEA or Wayfair within a 10-year timeframe. For this analysis, openLCA was utilized in accordance with the ISO 14040 and 14044 standards to help quantify the carbon emissions produced from the upstream, use, and downstream phases of the table. The functional unit identified was the number of tables used within a ten year "life span". The necessary information was compiled utilizing both primary and secondary sources. Making use of the database ecoinvent_38, a LCA model was created taking in mind the four main aspects namely table production, packaging, end-of-life treatment, and transportation. A LCA model was created for all 6 different tables that are to be examined. The tables with the highest to lowest environmental impact are: Wayfair low-grade, Wayfair commercial-grade, IKEA low-grade, IKEA commercial-grade, Wayfair reused, and IKEA reused. The carbon emissions for the tables range from 16.2 to 107.8 kg CO2 eq. The reused tables are found to have significant carbon reduction in comparison to its unused counterpart with up to 84.95% of the carbon emissions can be avoided in Wayfair and 60.51% for IKEA. Between the 2 companies, IKEA tables have lower GHG emissions, whether that is through sourcing a reused table from this brand or from a new product. Not only does giving a second-hand table another life and reduce its global warming potential, it is also the best monetary option. Over the course of the 10-year functional unit, the financial savings with the reused table is 99 CAD in comparison to the next inexpensive option. The presence of limitations in the analysis should be acknowledged. Future research should focus on addressing these gaps, particularly the scope of company selections, potential scenarios, and the inclusion of social aspects in the LCA.

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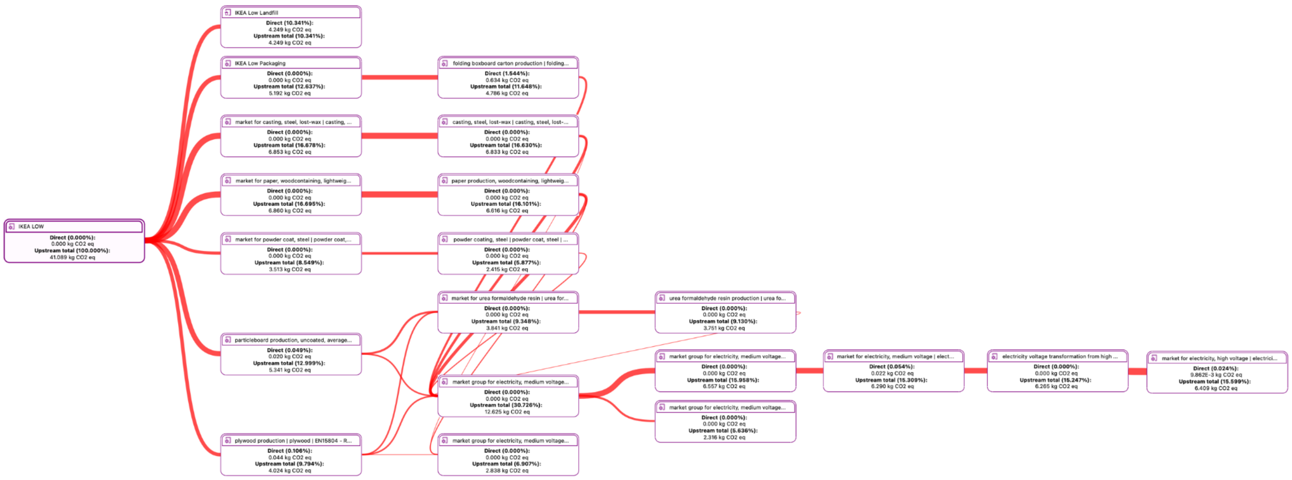
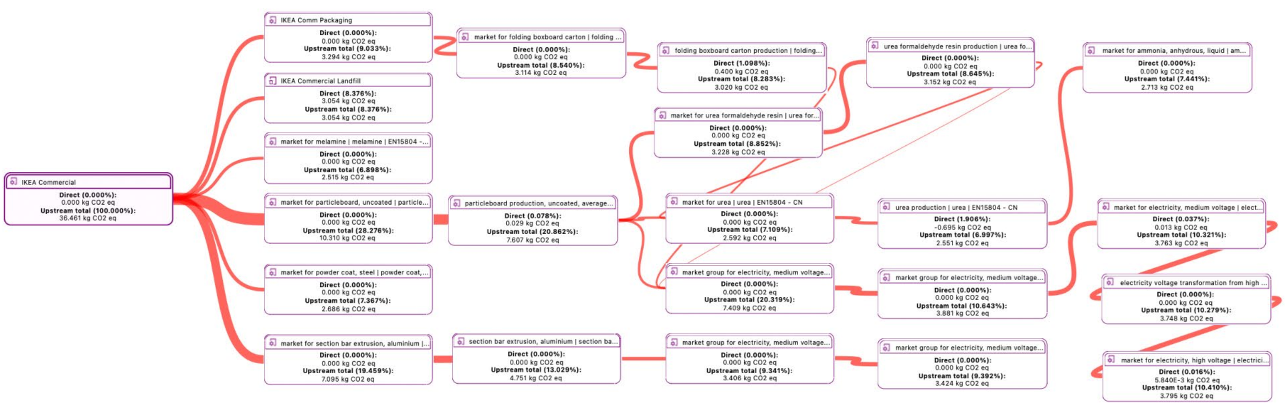
APPENDICES

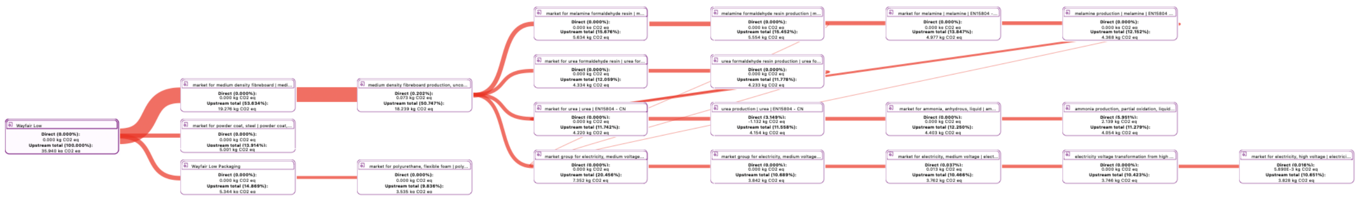
Appendix A: Sankey diagram for IKEA low-grade table showcasing the distribution of total kgCO2 eq



Appendix B: Sankey diagram for IKEA commercial-grade table showcasing the distribution of total kgCO2 eq



Appendix C: Sankey diagram for Wayfair low-grade table showcasing the distribution of total kgCO2 eq



Appendix D: Sankey diagram for Wayfair commercial-grade table showcasing the distribution of total kgCO2 eq